THE ENGINEER

A Seven-Day Journal

## The Tin Research Institute

The report of the Tin Research Institute for 1951 was published last week by the International Tin Research and Development Council. With its laboratory extensions opened in May, 1951, it has been able to undertake new investigations—notably the testing of alloys in bearings and the casting of bronze in long bar form. Its main interest has been, however, upon pilot stage work on electro-deposited tin-alloy coatings, particularly the tin-nickel coating process. The shortage of nickel has accelerated the development of a satisfactory commercial plant for this process and an installation of 2000 gallons capacity has been in operation near Birmingham for some months. Work on other tin alloys invented in its laboratories, such as the tin-zinc and tin-copper (Speculum) alloys is also described. The Underwood bearing testing machines were actively employed and exploratory tests were made on the new aluminium-tin on steel bearings. Work on hot-tinning and tinplate is noted and there is mention of a pewter which, whilst retaining its ductility, can by simple heat treatment be made almost twice as strong as the standard alloy. With regard to corrosion the report mentions its technical services to users of tin-coated metals. The report concludes with a summary of the extra-mural research work in hand and gives a list of publications issued by the Institute during the year.

## Air Traffic Statistics for 1951

The Ministry of Civil Aviation published last week its operating and traffic statistics of the airways corporations and their U.K. associates for the calendar year 1951. There were substantial increases in both the passenger and freight traffic compared with last year. Nearly 1¼ million passengers were carried during the year, being an increase of 22 per cent. Passenger miles flown increased by 35 per cent to over 1 million; freight short ton miles and mail short ton miles each increased by 28 per cent to 31 million and 17 million respectively. These results were achieved with an increase of 19 per cent in capacity short ton miles flown and an 11 per cent increase in aircraft miles. Overall load factors improved to 65 per cent for British Overseas Airways Corporation, 64 per cent for British European Airways, and 59 per cent for associates, compared with 58 per cent, 58 per cent and 48 per cent respectively for the previous year.

## Swiss Industry

At the last monthly luncheon of the Old Centralians, which was held in London on April 17th, a talk on "Swiss Industry" was given by Lord Verulam, the chairman of Enfield Cables, Ltd. Lord Verulam commented on the aptitude of the Swiss for precision work, and on the fact that the great majority of Swiss manufactured products were exported. One five-hundredth of the world's population was Swiss, he said, yet one-fiftieth of world trade passed through Swiss hands. Many specialist products were made in Switzerland better than anywhere else in the world, and he thought that a great deal of benefit would have come to this country if one or two of the many productivity teams which had been sent to the United States had, instead, gone to Switzerland. The principal export industry of Switzerland was mechanical and electrical engineering, but textiles, the manufacture of watches and instruments, foodstuffs, dyestuffs, and pharmaceuticals were also very important. During the course of his talk, and in the discussion which followed, Lord Verulam and other speakers mentioned several of the engineering inventions which had originated in Switzerland, and the work of several of the well-known Swiss engineering firms. The influence of the federal technical high school of Zurich on the high quality of Swiss work was also discussed.

## Lloyd's Register Shipbuilding Returns

Lloyds' Register of Shipping has issued its returns for the quarter ended March 31, 1952. Compared with the previous quarter, the 356 steamships and motorships of 2,270,621 tons gross under construction represented an increase of 61,609 tons, and of this total, ninety-six ships of 596,875 tons are afloat and the remainder are still to be launched. During the quarter fifty-six ships of 324,831 tons were commenced, sixty-two ships of 327,141 tons were launched and fifty-five ships totalling 267,511 tons were completed, while work was suspended on five ships, representing 1350 tons. There were ninety-eight ships of 716,853 tons under construction for registration abroad or for sale, an increase of 21,934 tons over the last quarter. Those ships represented 31·6 per cent of the tonnage building in this country. Oil tankers upwards of 1000 tons totalled 109 ships of 1,285,060 tons, representing an increase of 45,563 tons as compared with the last quarter and was the highest figure ever recorded. Plans have been approved and material ordered for 324 ships of 2,393,703 tons gross. Work in hand abroad, excluding China, Russia and Poland, totalled 3,409,947 tons gross, covering 868 ships, representing an increase of 124,894 tons over the previous quarter. During the quarter 196 ships of 754,202 tons were commenced, 171 ships, totalling 597,199 tons, were launched and 173 ships, amounting to 636,557 tons, were completed, while work was suspended on forty-two ships of 69,047 tons. Oil tankers over 1000 tons totalled 111 ships and the tonnage increased by 112,707 tons to 1,208,608 tons, which represented 35·4 per cent of the tonnage building. World construction has increased by 186,503 tons and at the end of the quarter amounted to 1224 ships of 5,680,568 tons gross, of which 40 per cent was in Great Britain and Northern Ireland. Of the total, 955,327 tons of steamships and 1,315,294 tons of motorships were under construction in Great Britain and Northern Ireland and the corresponding figures for construction abroad were 1,374,691 tons and 2,035,256 tons. Oil tankers building in the world amounted to 220 ships of 2,493,668 tons, an increase in the quarter of 158,270 tons, and representing 43·9 per cent of world construction. Building under the inspection of Lloyd's Register aggregated 3,692,262 tons, which was 65 per cent of the world total.

## Diesel Engine Users Association Annual Luncheon

On Thursday of last week the Diesel Engine Users Association held its annual luncheon at the Connaught Rooms, London. Mr. Gerald B. Fox, the president, who was in the chair, in proposing the toast of "Our Guests" referred to the troubles experienced with the early diesel generator sets both on board ship and in the laboratory. He mentioned the early days of the Association and commented upon its widening field of activities, particularly the working costs report. Vice-Admiral (E) The Honourable Sir Denis C. Maxwell replied on behalf of the guests and also gave the toast of "The Association." He briefly reviewed the growth of the use of the diesel engine by the Royal Navy. He said that it first appeared in 1903 and the submarine A.13 was fitted with a Vickers-M.A.N. engine in 1908, while diesel generator sets formed part of a battleship's equipment in 1910. Expansion was rapid and by 1940 about 225,000 h.p. was installed and this figure rose to 2,200,000 h.p. by 1945. Initially, Sir Denis continued, it was the practice to use suitable commercial engines but this led to multiplicity of designs and the problem of spare parts, so that a policy of standardisation was adopted, four sizes of engines being built by a number of manufacturers. Sir Denis went on to say that the Royal Navy required engines to satisfy requirements of minimum weight and space and maximum reliability, and had to consider world-wide operation and the possibilities of dilution of labour for production in wartime. The introduction of the A.S.R.1. engine was recalled and the Admiral mentioned that the A.S.R.2 model embodied light alloys to reduce weight. After referring to the engines for powering minesweepers and frigates, Sir Denis announced the development of a new two-stroke, high-speed lightweight engine of triangular form, having three crankshafts and developing 2500 b.h.p. Sir Denis then remarked upon the rearmament programme and mentioned that the Admiralty maintained its interest in the gas turbine. He stated that two prototype boats powered by 6000 h.p. machinery were being built, further auxiliary generators were under construction and experimental work was proceeding with small gas turbines of high power, space and weight ratio.

## Sir Stafford Cripps, Q.C., F.R.S.

Both during and since the second world war the engineering and allied industries have had perforce to maintain close and continuous contact with the Government of the day, and have been directly affected by prevailing economic difficulties. These are matters which frequently brought Sir Stafford Cripps, Q.C., during his years of office in the Government, into touch with engineers and engineering concerns, and his death, which occurred in Switzerland on Monday last, April 21st, after a long and painful illness, will be deeply regretted. Sir Stafford, who would have reached the age of sixty-three yesterday, was Minister of Aircraft Production in the Coalition Government for a period during the war, and when the Labour Government succeeded to office in 1945, he was appointed President of the Board of Trade, and, subsequently, Minister for Economic Affairs. On Dr. Dalton's resignation in October, 1947, Sir Stafford became Chancellor of the Exchequer, in which office he continued until October, 1950, when his precarious state of health compelled him to retire. There are many engineers and industrialists among those who, while not sharing Sir Stafford's political outlook, were repeatedly impressed by his integrity and by his mastery of detail in the various industrial and economic matters for which he took responsibility during his arduous years of office in the Government. As a young man, Sir Stafford achieved considerable distinction as a chemist, and during the first world war worked in the Explosives Department of the Ministry of Munitions and as Assistant Superintendent of the Government factory at Queensferry. He was elected a Fellow of the Royal Society in 1948.

# North of Scotland Hydro-Electric Schemes

## No. IV—THE MULLARDOCH–FASNAKYLE–AFFRIC PROJECT*

(*Concluded from page 526, April 18th*)

*The Mullardoch - Fasnakyle - Affric project is one of the larger of the North of Scotland Hydro-Electric Board's developments. The principal power station at Fasnakyle has an installed capacity of 66MW, and is supplied from a diversion tunnel, including a pressure tunnel, leading from the Benevean reservoir. There is a second and larger reservoir at Mullardoch, each reservoir being formed by a gravity dam. The estimated annual production of the scheme is 236 million kWh. Following the description of the storage and diversion works given in Parts I and II, we conclude with some details of the power station and the machinery installed in it.*

THE three short pipe-lines, leading from the pressure tunnel to Fasnakyle power station, are entirely buried. Each line is 8ft 4in in diameter and 809ft in length, the pipes being nearly 9ft in length with welded joints, except for one longitudinal riveted joint, made in the manufacture of the pipes. Each pipe leads from the trifurcation shown in the illustration below to the control valve at the entry of the casing of one of the three Francis turbines.

Testing of the pipes was carried out in a somewhat novel manner. The welded joint is shown in the accompanying sketch. The pipe was 1½in thick, and a weld the full depth was not required, so the asbestos filling compound shown in the sketch was introduced. Water at the test pressure was introduced into the tapped hole thus filling the small annular space enclosed by the welds, the cover strap and the pipe ends. The pressure was recorded at the opposite end of the cover strap. On proving the joint satisfactory in this manner, the hole was closed by a plug which was sealed by further welding. Two methods of making the joints are shown in the sketch, one made inside and the other outside the pipe. Pairs of pipes were joined together by the joint made on the outside, and each pair was then hauled into position in the pipe tunnel. The remaining joints were then made from the inside of the pipe. Near the power station, where the pipes were in a trench, a more simple weld without a cover strap was used, a length of each pipe-line close to the power station having a full circumferential butt weld to take the load of the turbine valve.

After laying, jointing and testing the pipes, concrete was packed round them by pump, and the crown of the tunnel grouted through 1½in dia. tapped holes in the pipes. The holes were then plugged, and the plugs sealed by welding. As a protection against corrosion, the pipes were shot-blasted and sprayed with 0·003in of zinc, followed by 0·003in of aluminium, and finally painted with three coats of bitumastic paint.

### Fasnakyle Generating Station

The power station is a steel-framed structure with reinforced concrete walls, and is faced with Burghead stone. It is shown in the accompanying illustration, complete except for the stone facing. The concrete was placed largely by pump, and during construction the river was diverted away from the power station site with an earth fill cofierdam. On completion of the work, it was allowed to flow back to its original course, alongside the power station. Model tests were carried out on the site to check the layout of the tail-race under all conditions of flow.

A cable tunnel leads under the road to the switching station, which is situated some distance away in an inconspicuous position. The turbine house floor is at 225ft O.D., which is about 7ft above the axis of the spiral casings. The alternators are set on reinforced concrete plinths, the tops of which are at a level of 232ft O.D. The interior of the turbine house will be imposing when it is completed; it is 65ft high, and there will be a terrazo faience 7ft 6in high round the walls, the walls above and the ceiling being plastered.

The administrative block and control room are spaciously laid out. It is intended at a later date to control the hydro-electric schemes in this area from Fasnakyle.

The three steel pipes which serve the turbines, are each provided with a hydraulic servo-motor-operated straight-flow turbine inlet valve at the power station. The water pressure for the operation of these valves is derived from the tunnel system, and each pipe supplies a vertical-shaft Francis reaction turbine, developing approximately 33,000 b.h.p., at the design head of 490ft. The gross static head is 525ft, and the maximum net head is 510ft.

### Turbine Inlet Valves

As mentioned above, the main valve of each turbine is a "straightflow" unit—a wartime invention developed by the makers. The Fasnakyle valves are actually the first of this kind to be put into commercial service in Great Britain, although some have been exported.

The "door" of the straightflow valve (see the accompanying drawing) is roughly hemispherical, one half of this hemisphere being solid and acting as the closing member while the other half is bored out to the diameter of the pipe and forms the "follower ring." Thus the valve is somewhat similar to a ring-follower valve, and is intended to combine to the merits of that valve (i.e., clean cutting through the water without diverting the jet), with compact arrangement and small frictional resistance to movement. The door is of cast steel with stainless steel (weld-deposited) seating faces, upstream and downstream for the seals. The service seal bears on the downstream side. It is operated by pipe-line pressure, is droptight, and can be attended to or replaced with the valve in-situ behind the protection of a positive (screw-operated) emergency seal, which bears against the upstream side of the door. Both the seals are of reinforced rubber, positively clamped between metal surfaces and while in this particular application the water pressures they have to withstand can be said to be moderate, a similar design, it is claimed, has been proved to be droptight up to a pressure of 700 lb per square inch.

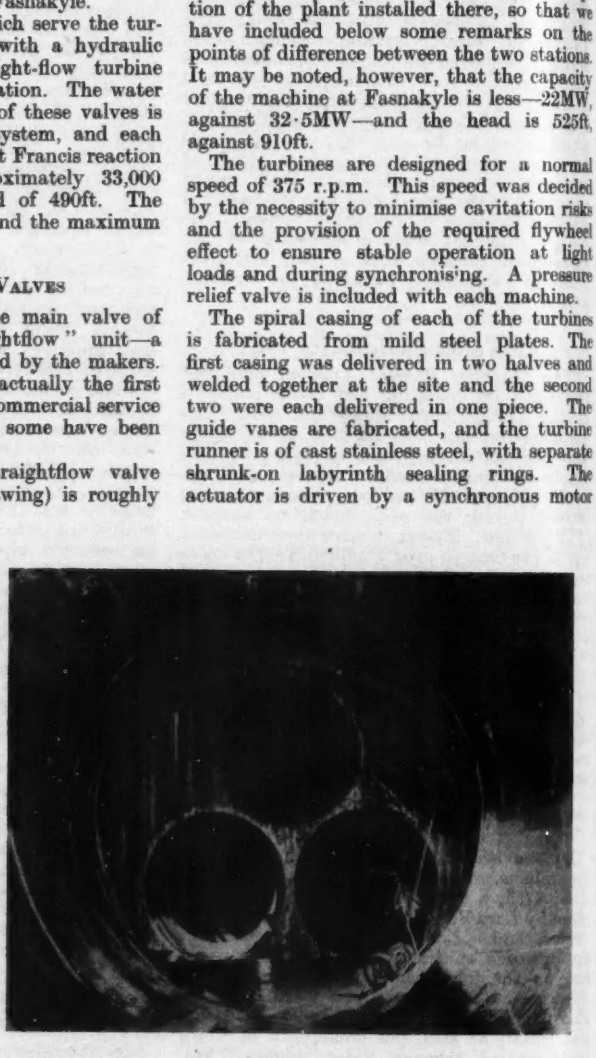
The valve body is of fabricated construction in halves, with gunmetal-lined trunnion bearings and a taper quadrant type of dismantling joint. The door is operated by a hydraulic servomotor, constructed of "Colclad" plate, i.e., mild steel plate which has had a stainless protective layer added to it in the rolling mill. The movement of the servomotor is given variable speed by a "travelling control screw" of the kind the makers have used on the cylindrical balanced valves, and the performance of the valve is smooth, even when closing under unbalanced conditions.

### Turbo-Alternators

There is considerable similarity between the generating plant at Fasnakyle and that at the Loch Sloy power station. Our article on the Loch Sloy scheme included a description of the plant installed there, so that we have included below some remarks on the points of difference between the two stations. It may be noted, however, that the capacity of the machine at Fasnakyle is less—22MW, against 32·5MW—and the head is 525ft, against 910ft.

The turbines are designed for a normal speed of 375 r.p.m. This speed was decided by the necessity to minimise cavitation risks and the provision of the required flywheel effect to ensure stable operation at light loads and during synchronising. A pressure relief valve is included with each machine.

The spiral casing of each of the turbines is fabricated from mild steel plates. The first casing was delivered in two halves and welded together at the site and the second two were each delivered in one piece. The guide vanes are fabricated, and the turbine runner is of cast stainless steel, with separate shrunk-on labyrinth sealing rings. The actuator is driven by a synchronous motor supplied by a separate alternator carried on the exciter shaft. Also, the turbine is suitable for running with the spiral casing empty when the alternator is operating as a synchronous condenser. Under such conditions, the runner seals are supplied with cooling water. No works tests were carried out on the first rotor unit, and the rotor was trans-



TRIFUCATION AT END OF PRESSURE TUNNEL

* No. I, "An Introductory Survey," appeared on July 14, 1950; No. II, "The Loch Sloy Project," on July 21–August 4, 1950; No. III, "The Fannich Porject," on June 8–15, 1951.

ported to site in parts, where the steel plates were shrunk on to the shaft. The complete rotor weighs 116 tons. The total maximum load on the thrust bearing of each alternator is 185 tons.

The alternators, which generate at 11kV, 3-phase, 50 c/s, together with the associated main and pilot exciters, are direct coupled to the turbines. The alternators have a nominal output of 22MW at 0·95 power factor lagging.

The separate governor alternator is mounted on the exciter shaft. The rotor poles are permanent magnets, but magnetising windings are provided for initial energising of the poles before generation and at any subsequent time if this is necessary. The stator of the governor alternator is mesh-wound.

The oil system of each governor gear is maintained by its own electric-motor-driven pump operated from the unit a.c. supplies provided for each set, but in addition a Pelton-driven oil pump is provided as a standby, which starts automatically if the oil pressure drops below the predetermined value.

The closed air circuit ventilation system on each alternator is provided with a unit cooling system by water pumped from the draft tubes and an alternative standby cooling water supply can be obtained from the spiral casing. About 25 per cent of the circulating air can be extracted from the ventilation system for station heating. Manually-operated $CO_2$ fire protection equipment is provided for the alternators and is under the control of the operator from the turbine gauge panel.

The air for station heating diverted from the alternator air system is exhausted into the inlet valve and relief valve pits and enters the turbine room through gratings in the floor. Louvres are provided to control the amount of air exhausted. Make up air enters the alternator as at Loch Sloy. The cooling water is obtained from a motor-driven pump provided adjacent to each set. A standby supply for each set is obtained through a pressure reducing valve from the spiral casing.

A 250kVA, 11,000/415V, 3-phase "ON" cooled transformer is provided for each machine direct connected to the machine terminals to supply the a.c. auxiliary motors associated with the particular machine on the unit principle. A standby supply is obtained from a similar 250kVA transformer.

The turbine house is equipped with an electric overhead travelling crane, provided with a 120-ton main hoist and 15-ton auxiliary hoist.

FASNAKYLE POWER STATION BEFORE CONSTRUCTION OF STONE FACING

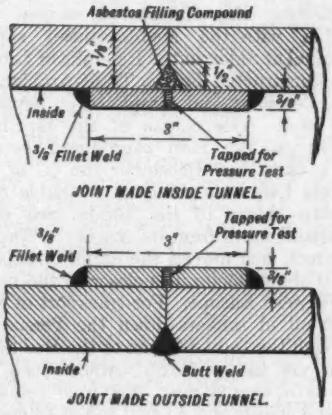
### Transformers and Control Equipment

The alternators are connected directly to step-up transformers, rated at 23,158kVA, with a ratio of 11/132kV. On-load tap changing gear is not at the moment provided on these transformers, but they have been designed to enable a tapping range of 0+15 per cent to be added later if desired.

The transformers, which are provided with "OFB" cooling are situated at the 132kV switching station, which is approximately 300 yards from the power station. Each alternator is connected to its associated transformer by three trefoil groups of 11kV cables, each conductor consisting of 0·6 square inch paper-insulated lead-covered cables.

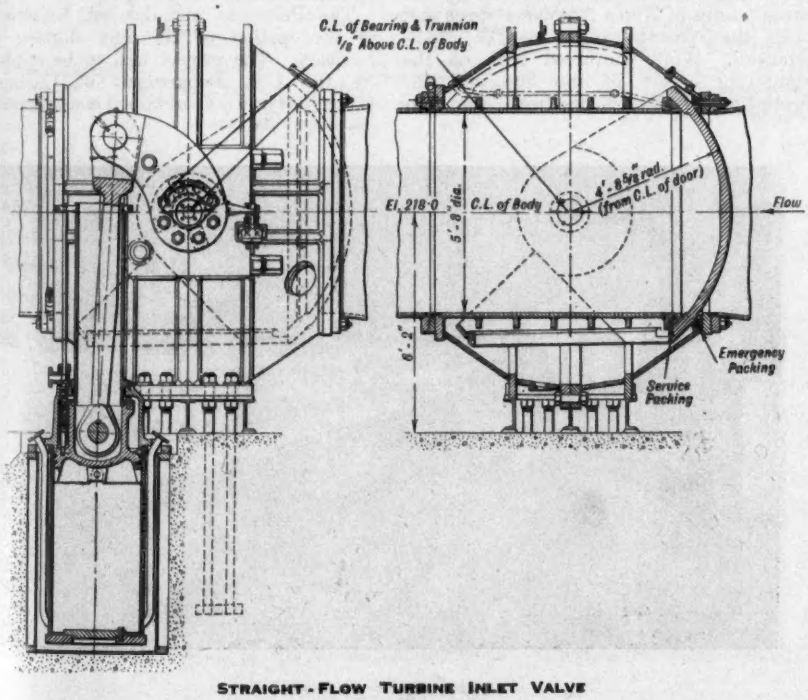
The 132kV switching station consists of a single busbar with five oil circuit breakers, each having a rupturing capacity of 1500 MVA. Three of the oil circuit breakers control the generator transformer circuits, whilst the remaining two oil circuit breakers control the two 132kV feeders to Beauly, approximately 20 miles distant.

The whole of the control gear situated at the power station and used for generator and switchgear controls, indications and alarms, is of modern, light current design consisting of miniature control panels and desk. Circuit breaker operation from the switching station is effected by direct light current control through pilot cables laid with the trefoil groups of power circuits.




DETAIL OF PIPE JOINTS

Control is as at Loch Sloy except that one control switch is provided for all the 132kV breakers and individual selection is carried out prior to operation of the control switch. The 415V common services board is a "Combination" fuse switch unit with hand-operated isolators for selection of alternative supplies. There is no auxiliary alternator, standby power being obtained from the local 11kV distribution system. The 132kV switchgear is also as at Loch Sloy, except there are three generator circuits and two feeder circuits and no bus section. Space is provided for extension at a later date to duplicate busbars. The structures for supporting the isolators and busbars are of reinforced concrete. Protection of the generator circuits and feeders is the same as that at Loch Sloy, single-zone, bus-zone protection of a simple form being provided. Auxiliary supplies at the switching station are obtained from 150kVA, 11,000/415V, auxiliary




STRAIGHT-FLOW TURBINE INLET VALVE

transformers with "ON" cooling connected direct to each main step-up transformer and a further 150kVA standby transformer; 250V, 110V and 50V d.c. batteries are also provided for protection and control.

Control and indications of the gates at Benevean, together with communication circuits, are provided over the cores of a stainless steel sheathed pilot cable strung overhead on the existing 11kV wooden pole line from the power station to Benevean. At present it is not proposed to provide any controls or indications from the Mullardoch dam, although further consideration will be given to these facilities later.

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The consulting civil engineers for the Mullardoch–Fasnakyle–Affric project are Sir William Halcrow and Partners, and the principal civil engineering contractor is John Cochrane and Son, Ltd. The model tests for the side-stream intakes were carried out under Professor Allen at Aberdeen University. The architects are Messrs. Shearer and Annand. The consultants for the electrical and mechanical work are Messrs. Kennedy and Donkin. The main contractor for the turbo-alternators is the English Electric Company, Ltd., much of this plant being manufactured at the works of Harland and Wolff, Ltd. Other contractors are listed herewith: 120-ton crane, Sir William Arrol and Co., Ltd.; cables, Scottish Cables, Ltd.; generator transformers, power station auxiliaries, switchgear and "straight-flow" valves, English Electric Company, Ltd.; batteries, Pritchett and Gold and E.P.S., Ltd.; miniature direct control equipment, Standard Telephones and Cables, Ltd.; automatic voltage regulators, Metropolitan-Vickers Electrical Company, Ltd.; lighting and heating, James Scott and Co. (Electrical Engineers), Ltd.; pilot cables for dam controls, Pirelli-General Cable Works, Ltd.; 11kV wooden pole lines, J. L. Eve Construction Company, Ltd.

# The Trans-Arabian Pipe-line "Tapline"

By V. S. SWAMINATHAN, M.A., M.Sc.(Lond.)

No. I

*The Trans-Arabian Pipe Line Company completed the oil pipe-line "Tapline" on September 25, 1950. "Tapline" traverses four countries—Saudi Arabia, the Hashimite Kingdom of Jordan, Syria and Lebanon, and makes the oil resources of Saudi Arabia available on the eastern shores of the Mediterranean. The line is 1068 miles long and has an initial capacity of 300,000 barrels per day, and its operation releases sixty-five oil tankers for other routes.*

"TAPLINE," the abbreviated name for the world's biggest oil pipe-line system connecting the oilfields of eastern Saudi Arabia with the Mediterranean shipping terminal at Sidon in the Republic of Lebanon, was constructed by the Trans-Arabian Pipe Line Company and completed on September 25, 1950. The course of the pipe-line is shown in the map reproduced herewith. Since early last December the oil of Saudi Arabia had been rendered available on the eastern shores of the Middle Sea over a thousand miles from its source. "Tapline," in effect, has moved the Saudi Arabian oilfields about 3500 miles closer to the markets of Western Europe. For transport of Middle East oil in tankers down the Persian Gulf through the Indian Ocean to the Red Sea and then via the privately owned Suez Canal meant a twenty-day, 7000-mile round trip for the vessels and a canal toll of 18 cents per barrel, or 40,000 dollars for the oil in each big modern tanker.

The Trans-Arabian Pipe Line Company's system is, in fact, composed of two sections under different ownership and operation. That part of the line beginning at Qaisumah in North-East Saudi Arabia and extending north-west 753 miles to Sidon, is owned and operated by the Trans-Arabian Pipe Line Company. The 315 miles of pipe-line stretching east and south from Qaisumah to one of the world's major producing oilfields at Abqaiq forms the hub of the gathering system of the Arabian American Oil Company (Aramco), who own and operate it. This eastern section can be used either for collecting oil and delivering it at the Persian Gulf shipping port of Ras Tanura, or for a westward journey through the royalty gauging tanks at Qaisumah to the Mediterranean shipping terminal. The Aramco-owned part of the line links with its producing fields and can be connected to future fields as they are discovered and developed.

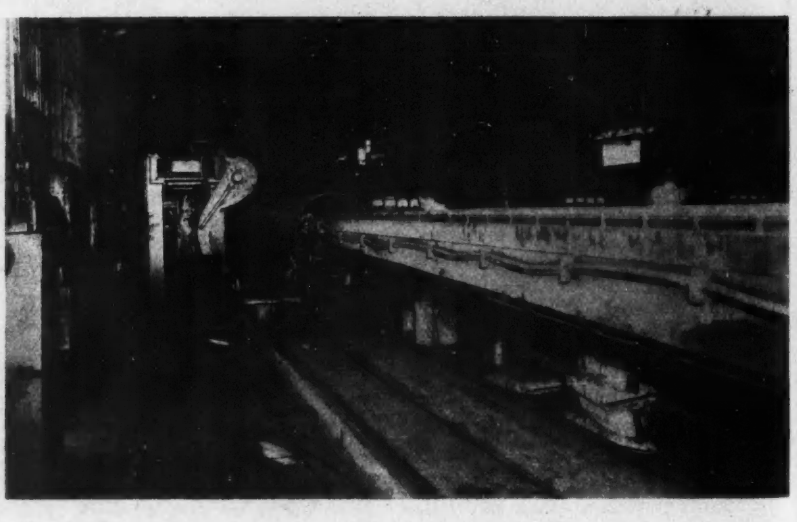
Ownership of Aramco, the producing company, and Trans-Arabian, the pipe-line company, is divided among the following interests:—Standard Oil Company (New Jersey), 30 per cent; Standard Oil Company of California, 30 per cent; The Texas Company, 30 per cent; Socony-Vacuum Oil Company, 10 per cent.

The genesis of this mammoth undertaking is briefly as follows. Early in 1944 a recommendation was made by the U.S. military authorities for the construction of a trans-Arabian pipe-line as a project of the wartime Petroleum Reserves Corporation. This plan fell through, but Aramco experts made a careful study of the scheme, and decided that a pipe-line half again as big in diameter as the Big Inch might be laid across the barren wastes of North Arabian steppes and across the coastal ranges to the Mediterranean. Work continued both on the engineering aspect of the line and the negotiation of agreements with the four countries through which it would pass, prior to the appointment as president of Burt E. Hull, who, forty odd years ago, built the first big oil line from Tulsa to Port Arthur, and the Big Inch and Little Inch lines during the second world war.

Several formidable obstacles had to be overcome before the consummation of the project. They were, briefly, difficulties of terrain, climate, the Palestine conflict, sudden suspension of quarterly licences by the Office of International Trade (O.I.T.) of the U.S. Department of Commerce, the training of Arab workers and water supply *en route*. The pipe-line route crosses heavy sand dune country only on its first 100 miles at the east end, and further west for 750 miles it traverses absolutely barren desert land to the Jordan frontier. Here the average yearly rainfall is only 3in, and normally no rain falls from April to November inclusive. The surface of this 750-mile stretch is either level or gently sloping, and is about evenly divided between smooth gravel plains, disintegrated limestone over hard limestone strata, and level country with 2in to 6in of top soil covering limestone tough enough to need blasting for removal. The line attains its highest elevation, 2975ft above sea level, before it leaves Saudi Arabia. The 80-mile route across Jordan proved the most formidable section of the entire route, since the surface was completely covered with hard basalt, and volcanic lava, weathered in chunks ranging from a few pounds to as much as several tons. The stretch of just over 100 miles across Syria resembles West Texas and New Mexico in many ways. Approaching the Syria-Lebanon frontier the line descends a steep escarpment into the southern end of the Bekaa Valley, which runs north between two mountain ranges, the Lebanon and the Ante-Lebanon, and here it crosses several creeks, the only streams of running water it encounters.

This was the type of terrain over which it was decided to lay the world's greatest pipe-line. Added to these features is the fact that the summer temperature rises to 130 deg. Fah. with a humidity below 7 per cent. In such a climate a man needs a minimum of 2 gallons of water to drink daily, and metal surfaces become too hot to touch with the bare hand.

The Palestine war delayed construction of the section of the line skirting that territory. The project had to be approved by the U.S. Department of Commerce. When that had been obtained it was necessary



FABRICATION OF PIPES

*"Tapline": General Data*

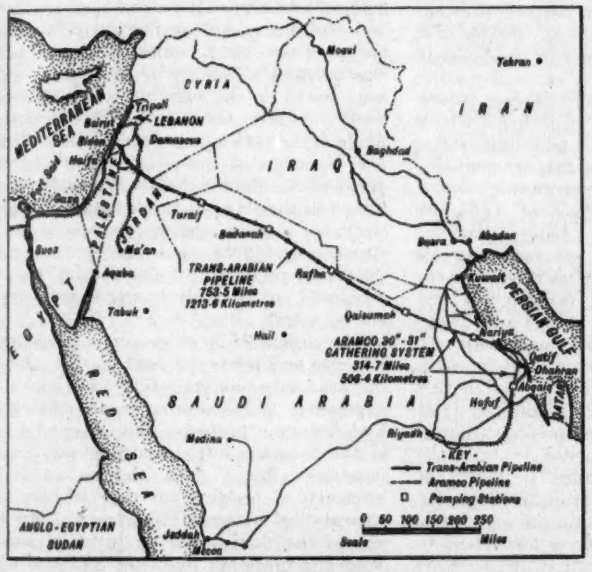
| | Aramco 30in to 31in gathering facilities | Trans-Arabian pipe-line | Total |
|---|---|---|---|
| Maximum throughput, ... ... ... ... ... ... ... ... | 300,000 B.P.C.D. | 300,000 B.P.C.D. | — |
| Length and size of pipe ... ... ... ... ... ... ... ... | 314·7 miles, 30in to 31in O.D. | 747·4 miles, 30in to 31in O.D.<br>6·1 miles, 22in and 24in O.D. | 1,062·1 miles, 30in to 31in O.D.<br>6·1 miles, 22in and 24in O.D. |
| Total ... ... ... ... ... ... ... ... ... ... ... | | 753·5 miles | 1,068·2 miles |
| Volumetric contents of main line ... ... ... ... ... ... | 1,445,100 barrels | 3,454,400 barrels | 4,899,500 barrels |
| Total crude oil and bunkering tankage ... ... ... ... ... | 2,384,000 barrels | 3,363,000 barrels | 5,747,000 barrels |
| Total number of pumping stations ... ... ... ... ... | Two | Four | Six |
| Total rated horsepower of pumping and generator prime movers | 26,110 b.h.p. | 50,020 b.h.p. | 76,130 b.h.p. |
| Estimated final total cost ... ... ... ... ... ... ... | 62,000,000 dollars | 168,000,000 dollars | 230,000,000 dollars |

B.P.C.D.—Barrels per calendar day. O.D.—Outside diameter.

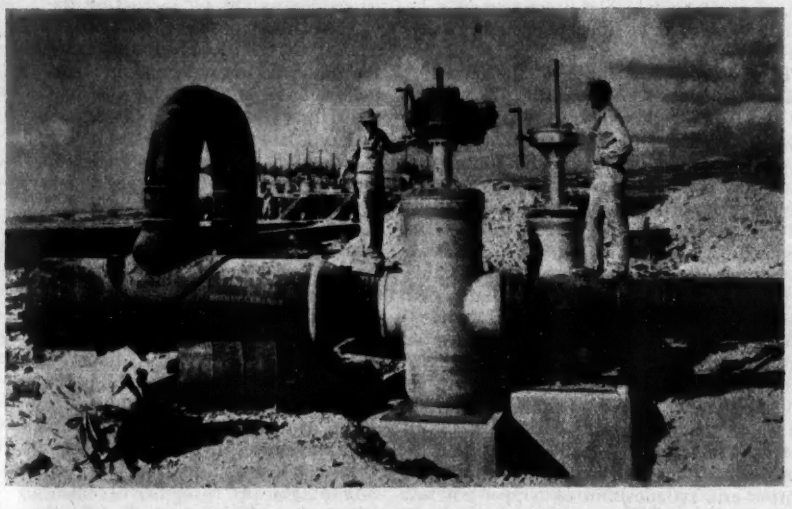
*Pipe Distribution Installed (Mileage)*

| 30in × $\frac{7}{16}$in | 30in × $\frac{3}{8}$in | 30in × $\frac{5}{16}$in | 30in × $\frac{1}{4}$in | 31in × $\frac{1}{4}$in | Total |
|---|---|---|---|---|---|
| 16·28 ... ... | 210·42 ... | ...208·75 ... ... | 97·65 ... ... | 529·03 ... ... | 1062·1 |
| 22in × $\frac{1}{4}$in at end of "Tapline" ... ... ... ... ... ... ... ... ... ... ... ... ... ... | | | | | 4·7 |
| 24in × $\frac{1}{4}$in at station by passes ... ... ... ... ... ... ... ... ... ... ... ... ... ... | | | | | 1·4 |
| | | | | | 1068·2 |

to secure quarterly licences of the O.I.T. The first three such licences were issued, which enabled "Tapline" to make satisfactory progress. The licences, however, were suspended presumably because of complaints that in a time of shortages in the U.S. there should be no such large shipment of critical materials to far parts of the world. This left "Tapline" with a fleet of fifteen "Liberty" ships under charter from the Isthmian Line for the carriage of pipe-line material, and the company had to find alternative employment for this tonnage, while most of the American personnel on the job was flown home. Work was retarded to a production speed governed by the amount of pipe and other materials already in hand. Altogether, a full year was lost before the O.I.T. decided to resume licences for export. With the difficulties of language and inexperience largely overcome the company had nearly 14,600 Arabs in its employ and less than 2000 Americans, both on the job and at home. Most of the Arabs had seldom seen such simple tools as a screwdriver or a monkey wrench, and yet in time they became skilled workmen in a score of Western trades. They drove giant trucks, bulldozers, diggers and trenchers, blasted rock and welded pipe. They operated the self-propelled cars of the "skyhook" at Ras el Mishaab, built to swing 10-ton loads of pipe 3 miles through the air from the man-made sea island in the Persian Gulf. The more proficient, became sub-contractors in their own right, employing from twenty-five to 1000 other Arabs. Lastly, there was no water well, no oasis, anywhere within reach of the pipe-line from the Persian Gulf to the frontier of Lebanon. Since each of the thousands of "Tapline" workers required 2 gallons of water a day with copious dosing of salt tablets, water trucking became a major problem demanding an early solution. Of fifty-two wells drilled, forty brought in water, and as soon as the first brackish water was pumped to the surface apparently every Bedouin in Arabia came to know of it. The horizon was darkened with the converging tribes who made their camps by the precious water. By the summer of 1950, "Tapline" was supplying free water, all along the line, to more than 150,000 camels and perhaps double that number of sheep and goats, and nearly 100,000 Bedouins had by then set up camp around the water holes.




MAP OF PIPELINE



LINE SCRAPER TRAP

Line scrapers were run through it to clear out the sand and bits of metal. "Tapline" obtained on loan from the A.E.C. capsules of irradiated cobalt (cobalt 60), which were placed in the line scrapers and thus pipe-line walkers with Geiger counters were able to spot the scrapers at any time, and make definite reports on their progress. After the "pipe pigs" went through the line, trailed by clicking Geiger counters, water flowed slowly along for the requisite hydrostatic pressure tests. Following it came the oil of Saudi Arabia, and it took approximately 4·9 million barrels to fill the line before one barrel could be drawn off at Sidon. The first batch was pumped in at the east end on July 18, 1950. In addition, working stocks of nearly one million barrels at the western end and other working stock at intermediate pumping stations had to be accumulated. In all about six million barrels of oil had to be in the pipe and pipe-line tanks at all times just to keep the operation going. This quantity, incidentally, is more than all the oil pumped daily from all the wells in the United States.

When the main pump stations are completed each will be the centre of a small town, a fenced area totalling some 125 acres, with a tall radio tower for carrying on the business of maintenance and operation, and linking the Americans and Arabs living on

each station with the outer world. The addition of six lesser pump stations, or looping the line, will eventually bring its daily oil delivery to the Mediterranean to 500,000 barrels.

The main 30in to 31in pipe-lines of both Aramco gathering facilities and "Tapline" were tapered in wall thickness to reduce the initial cost and steel requirements to a minimum, based on balanced pumping conditions with twelve pumping stations at a maximum capacity of 500,000 barrels per operating day. But initially only six stations are being installed with a maximum capacity of 300,000 barrels per operating day.

All of the 30in to 31in pipe was manufactured by Consolidated Western Steel Corporation at Maywood, California, from plate supplied by the Geneva Utah mill. The plate was rolled into cylinders and longitudinally welded by the submerged arc process. The joints were later hydraulically expanded in giant dies to the exact outside diameters and this cold expansion process increased the yield point to a minimum of 52,000 lb per square inch. In calculating the required pipe wall thickness a maximum hoop stress of 65 per cent of nominal yield, or 38,000 lb per square inch, was used. Based on this limitation and a minimum wall thickness of ¼in the pipe distribution shown in the table was installed. Fabrication of the pipes is shown in progress in the illustration on page 556.

"Tapline" ordered its pipe to be built, half in 31in in diameter and the other half 30in. Then each 30in length was nested in a 31in length and even in the 30in lengths much material such as cement was stowed. Thus, the shipping cost of pipe was reduced by more than half, the speed of delivery more than doubled.

*(To be continued)*

# The Institution of Naval Architects

## ANNUAL SPRING MEETING

No. III—*(Continued from page 544, April 18th)*

THE second joint paper read on Thursday afternoon, April 3rd, was :—

### HIGH-POWERED SINGLE-SCREW CARGO LINERS

By W. H. Dickie


Summary

In 1945 the managers of the Blue Funnel Line embarked upon an extensive building programme, which included a number of fast single-screw cargo liners of two classes, namely, "P" and "H." The "P" class served the Far East and "H" class served Australia, and each is powered by double-reduction geared turbines of high power, driving a single screw. This latter feature is the subject of the paper which amplifies information and records in greater detail design particulars, construction and performance, which when projected marked an advance in single-screw propulsion. Form and model test results are tabulated and the body plan of the "P" class given. The reasons for adopting single-screw turbines in preference to diesel engines are discussed and the relevant figures are compared. Many detailed problems concerning such items as tail-shaft liners, propellers, gear wear, condensers, oil fuel combustion and control of the main engines are examined and the solutions arrived at are stated.


### Discussion

Mr. R. B. Cooper : The remarks concerning the improvement obtained by changing the design of the oil fuel burners are interesting, since all oil fuel burner manufacturers have changed their designs since the war. Here is an economic ship, with economisers and air heaters, and yet a saving of very nearly 2 per cent of fuel could be made.

The air pressure available from the fans is important and it is possible to change the burners and use the same fans and also increase the draught to the burner and therefore achieve better combustion. The table on superheat gives the number of burners per boiler and the steam temperature. The air pressure, after modification of the oil-burning technique, is 8in, and yet the steam temperature is down because combustion was being completed in the furnace. That indicates that there was a higher draught loss through the burners and a higher velocity of air to mix with the oil for producing better combustion. To effect good combustion we must have a precision-made atomiser with very fine clearances and a knife edge orifice, which is very easily damaged, and a device whereby the sprayer remains clean. The question of soot deposits is tied up with atomiser cleaning and with the present grade of fuel oil, and using an average burner consuming 8 tons of oil per day, it is possible that 5 cwt of soot will be formed in the boiler in the course of a week.

Mr. H. N. Pemberton : Large power, single-screw tankers are projected both in Europe and the U.S.A. and these ships, up to 40,000 tons deadweight, transmitting 20,000 to 22,000 s.h.p. through a single screw, present operational problems of which we have little experience. Large diameter propellers of low r.p.m. are necessary for good propulsive efficiency at high powers, and there are difficulties peculiar to large propellers associated with stern frame design in ships having propelling machinery aft. Adequate propeller aperture clearance is essential in order to avoid excessive propeller excitation, torsional, lateral and axial, of the dynamic system comprising turbines, gearing, shafting and propeller.

Where aperture clearance is less than about 6 per cent of the propeller diameter, there is danger of serious torque and thrust variations and large transverse forces become available for causing vibration of the ship's hull. The propeller, stern frame and rudder comprise the governing factors in the maximum power which can conveniently be used in single-screw ships, particularly with engines aft.

The slackening of the liner has occurred with new ships having shafts of normal size and it is attributed to insufficient clearance in the stern tube bush, or to the swelling of lignum vitæ when the fitting-out period has been unduly prolonged. Perhaps with very large shafts the bush clearances and the size of water grooves will not be adequate if based on established practice for normal diameter shafts. This trouble has also been associated with laminated plastic bearings, and it is generally understood that an ample supply of forced water lubrication is essential with these synthetic bearings.

With reference to the tailshaft liner which had been "destannified," I think that an electro-chemical process has caused selective corrosion of the tin in the alloy and also the solution and redeposition of copper ; it is a similar process to that of "dezincification." It is unusual for this type of corrosion to occur with the zinc and tin contents normally used for tailshaft liners, and since tin is cathodic to iron and steel the potential difference between the shaft and the ship's structure would, I think, lead to corrosion of the steel and not to the "destannification" of the brass.

Mr. G. J. Innes : The reference to tank tests and rudder thicknesses recalls some tank tests made on semi-balanced rudders of different shapes, where the results showed very appreciable differences, summarised in the fact that an aerofoil form produced much more satisfactory results than did any of the other alternatives submitted.

The shipowner is concerned, from the point of view of the efficiency of the machinery, with the amount of fuel needed to transport a specified quantity of cargo a specified distance, and over a course of voyages there are fractional differences in speed which when corrected to a common mean show that the fouling of the hull is the most serious factor in the running of a ship.

Professor L. C. Burrill : At the time when the design was considered, the power of 14,000 b.h.p. in a single screw was a new venture and represented a definite step forward. Propeller makers had had some experience with powers not greatly inferior on several ships, and they were able to advise the owners with some confidence, and the owners, builders, engineers, and propeller manufacturers co-operated for a period of two years before the final decision was taken. Preliminary investigations, which were made on the basis of systematic data, were confirmed not only by the comparisons made in the tank as between the three-bladed and four-bladed propellers, but also the performance figures deduced have been confirmed in the ships. I think that goes a great way to counter the suggestion made in America last year, that our control of the propeller problem by calculation has not advanced considerably in the last twenty or thirty years.

The design of a single-screw propeller of this size and power was not merely a matter of academic consideration, but involved experience and compromise, in addition to hydrodynamic problems. The size and weight of the propeller introduced new problems of handling, fitting and slewing, and the intensity of pressure on the tailshaft liner was also of extreme importance. For this reason the final screws were made smaller than the optimum diameter and less blade surface was adopted than would be indicated by the usual analysis, while steps were taken to reduce weight by discussing the strength of the blades at each radius.

Despite the design limitations, the performance is extremely good and the propellers have stood up to the high loading they have been carrying. Again, it is of interest that the blades were of aerofoil type throughout, despite the high loading, and it has not been found necessary to turn over to a less efficient section.

Mr. F. McAlister : My interest in this paper is the choice in the mode of propulsion. In the early days of marine engineering, slow-running paddle wheel engines were geared up to the first screw propeller vessels and single-screw machinery development proceeded quickly up to the Cunard liners "Etruria" and "Umbria," of 14,500 i.h.p., and having large compound engines with the l.p. cylinders 105in in diameter. Further advances in the size and power of ships inevitably produced twin-screw propulsion, with consequent disadvantages in propulsive efficiency and manœuvring from rest, offset by the advan-

tage of additional security by multiplication of power units.

In the middle of the 1930s a great deal of attention was paid to the forward development of high-powered single-screw vessels. There is a difference between multiple screws and single screws, in that the wake behind a single screw is much more varied than behind the multiple-screw shaft bracket. It is this large variation in wake which brings propellers of about 15,000 h.p., designed with reasonable area, thickness and other normal features, up to the borderline of trouble.

We are talking of the step forward taken in 1945, to 15,000 h.p. single-screw vessels, whereas to-day we are concerned with 20,000 h.p. single-screw vessels and possibly higher powers. Propellers for such vessels can weigh 45 tons, requiring a total melt of up to 70 tons of bronze, and they are bound to cause more than usual thought concerning design, material and manufacture.

Mr. S. Archer: One of the chief difficulties with gearing defects such as pitting, wear and scuffing is to know whether the trouble is progressive or static, and it is interesting to note the author's use of sulphur casts. This material suffers from a number of drawbacks: it requires just the right amount of heat in melting, it is brittle when set, and usually needs some mechanical stiffening. A much more convenient material is now available; it is applied cold and takes a faithful impression. It is a synthetic resin of the semi-thermosetting type; it sets in less than half an hour with an initial expansion of less than 1 per cent and subsequent contraction of 6 per cent.

A number of owners do not fit torsionmeters, and in consequence cases of serious gear tooth wear, pitting and scuffing caused by over-driving are by no means uncommon.

There is reason to believe that many gearing troubles are initiated when operating conditions impose heavy fluctuations of loading, as under torsional vibration or when pitching heavily in a seaway. In the latter case, owing to the high inertia of the turbine rotors and gears, practically the whole of the propeller torque variation will be transmitted to the gears with negligible change of speed. With the propeller periodically losing and regaining immersion the load on the gears may vary from almost zero to full-load torque several times a minute for long periods.

Another suspected source of trouble, particularly scuffing, has been the sudden or heavy-handed operation of the main steam controls during manœuvring, causing excessive tooth loads at relatively low speeds when oil films have not built up sufficiently.

Most existing torsionmeters do not give an indication of the magnitude of such torque variations, and there is a real need for a direct-indicating torsionmeter to give a visual warning of the instantaneous values of the torque fluctuations. A prototype instrument of this nature is on experimental service, and it is expected that accuracies of the order of 2½ per cent should be obtainable.

Professor E. V. Telfer: Why should Mr. Dickie be worried about the rudder area being too big? I cannot see why that should be troublesome, unless he is thinking that it will take too long to put the rudder over, as compared with one of less area. In my paper on seakindliness I gave a formula to determine the area of rudders, and the figure obtained from that formula is exactly the value used.

I feel that the experiments carried out to decide whether the single-screw ship suffers any penalty as compared with the more normal twin-screw ship are not sufficient to decide the issue. Two models of the same size will not determine the true ship comparison between the single-screw and the twin-screw types, because the beneficial effects of weight are much more evident on the single-screw model than on the twin-screw model, and the benefit of the single screw on the model size will disappear on the full-size ship.

It is essential, in view of the powers we are proposing to put through single screws now, to develop the efficiency of the design. We should concentrate on the improvement of twin-screw design, because the single screw is being pushed too hard.

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On Friday morning April 4th, the last day of the meeting, the session began with a paper entitled:

## STRUCTURAL STRENGTH INVESTIGATIONS ON DESTROYER "ALBUERA"

By D. W. Lang, B.Sc. (Eng.), and W. G. Warren.

SUMMARY

At the end of the last war the Admiralty agreed that one of the surplus destroyers could, before scrapping, be used for structural strength experiments.

There were no vessels of all-welded construction amongst those available, but there were some ex-battle class destroyers representing modern design of riveted construction. "Albuera" was chosen as the vessel most suitable for these experiments.

Although several full-scale structural tests of longitudinal strength had been carried out since the "Wolf" experiment in 1905, no such tests had been made on a British warship. It was therefore decided to conduct a series of longitudinal bending tests culminating in a final loading to complete collapse of the hull, to confirm that the existing methods of design were capable of giving reasonable predictions of the true state of stress.

Three major trials were planned, two with the ship afloat, namely:—A series of loadings to subject the ship to hogging and sagging moments sufficient to produce a maximum stress of about 5½ tons per square inch in the main hull structure; and a series of loadings similar to those in Trial I, during which stress distribution at the "break of forecastle" was measured; and the third with the ship in dry dock, the ship being supported at two positions amidships and subjected to an increasing hogging moment until major structural failure occurred.

There were also the following subsidiary objectives:—To measure the hull deflections under load; to observe the wrinkling of the ship side plating under high shear loads; to observe the effect of temperature gradients on deflections; and to observe the method of collapse and to compare the actual load at collapse with the values obtained by the use of various theories.

With regard to the main objective, the general conclusions are:—No allowance need be made for rivet holes in calculating the moment of inertia of the section; all continuous longitudinal material can be considered as fully effective; and the simple beam theory gives correct values for mean stresses, but underestimates the stress near the deck edge and overestimates the stress near the centre line.

This paper is primarily concerned with Trial III, in which the vessel was loaded to the point of collapse whilst in dock.

Mr. V. G. Shepheard: The "Albuera" trial was deliberately planned to continue right up to the point of major structural failure. The experimenters in "Albuera" had available to them the technique of instrumentation used in "Neverita" and "Newcombia," and post-war trials owe most of their advance over earlier experiments, such as those on "Wolf," to the great advances which have been made in instruments and recording techniques. It is easier to record strains than to interpret them, and a great deal of thought should be devoted to the positioning of gauges so that the full information sought is acquired with the fewest number of readings.

Professor Biles, in his paper on the "Wolf" experiment, said: "Within the limits of elasticity it will probably be more nearly accurate to make no deduction for rivet holes." In "Albuera" the rivet holes were neglected in calculating the inertia of the test section and there is excellent agreement between observed stresses and those calculated by the simple beam theory. Recent stress analysis work by photo-elastic and similar methods has also justified this assumption.

In the "Wolf" experiments the agreement with theory was not as close as desirable, and the discrepancy was explained by adopting a value for Young's modulus different from that found for the steel in an ordinary tensile testing machine. The "Neverita," "Newcombia" and "Albuera" results all seem to show that there is no significant discrepancy between measured strains and those predicted by the simple beam theory, so it is possible that the discrepancy in "Wolf" was due to the inferior gauges and recording technique in use in those days.

Another point of interest is that no rivet slip was observed and that the readings remained linear up to stresses of about 10 tons per square inch, and even beyond this only compressive members showed departure from linearity. The variations between maximum and minimum values of yield stress are disturbing for steels made to the rigorous specifications of the Admiralty.

We must remember that the results are "heart of plate" stresses, and it would be informative if the authors could give a few typical and some extreme cases of differences between surface stress and "heart of plate" stress. It would also be of interest to compare the direction and magnitude of the maximum principal stresses with the mean longitudinal stresses.

Dr. S. Livingston Smith: Experience in the B.S.R.A. has shown that, in addition to thermal stressing, it is necessary to correct for differential temperature effect between the strain gauges and the plating. The strain gauges are of very low heat capacity and, if there is a change of temperature, they change more rapidly than the plating to which they are attached. To meet this situation we attach thermocouples in pairs, one on a gauge and one on the adjacent plate.

I find it difficult to understand why it was decided to test the ship to destruction in the hogging condition. The manner of loading makes the failure conditions very unlike those experienced under the worst service conditions, and in the final condition of Trial III the manner of supporting gives an unusual distribution of shearing force and bending moment; the maximum bending moment and maximum shearing force being nearly coincident. If the vessel had been sagged with the supports towards the extremities of the ship it would have been possible to obtain a more conventional type of loading over the centre length of the ship.

Was consideration given to the direct measurement of the loads on the supporting towers, and were any measurements made with the object of measuring rivet slip?

Purely symmetrical loading is always difficult to achieve, and I feel that more gauges on the starboard side of the ship would have added to the value of the results. It would be interesting to see diagrams giving the distribution of transverse and shearing stress and the principal stresses with their angles of orientation. Were the longitudinal stresses computed with regard to transverse strains?

Professor A. M. Robb: It is stated that the collapse of the structure occurred in the region of maximum bending moment, but the collapse of the structure also occurred in the region of maximum shearing force, so that we are left with the problem as to whether

the collapse of the structure was associated with buckling under local load, and there is evidence to show that shearing force or shearing stress does enter largely into consideration.

The statement that all continuous longitudinal material can be considered as fully effective is not supported by the evidence. From the diagrams you will notice that in the hogging condition the stress at the centre line is actual stress, and it is less than one-fifth of the calculated stress, and in the sagging condition the stress at the centre line is about a quarter of the calculated stress. Looking at other distributions, you conclude that there is an effect from a hatchway.

The modern development of the destroyer has gone slightly astray from the structural point of view; the forecastle has become longer and longer until we have now a severe discontinuity at just about the region of maximum bending.

Professor E. V. Telfer: It is obvious that the deck stresses show there is absolutely no agreement with the simple beam theory. Apart from that, they are in much more complete agreement with the early work of Dr. Lockwood Taylor, and I think that one grave omission from this paper is an example showing how the Taylor calculation would have helped to explain the actual stress distribution across the deck.

Professor Robb suggested that the loss of stress towards the centre line might have been due to a hatchway. If that is so, it was quite wrong to have made experiments in way of such marked discontinuity, and that they should have replated the hatchway. The authors make no comment on what was the actual structure modulus. There is another experiment they could have made before placing the vessel in dry dock; it would have been useful to have used Lloyd's vibration exciter to have made the ship vibrate and to arrive at the modulus by experiment.

I hope that in future papers the authors will explain more of what they have found, for it is much more interesting to discuss fundamental problems rather than the pure instrumentation.

Mr. I. M. Youille: The third conclusion given in the paper states that "The simple beam theory gives correct values for mean stresses, but underestimates the stress near the deck edge and overestimates the stress near the centre line." It has been suggested that modifications to the simple beam theory to include the effects of shear may account for this. I suggest that this may not be the case. Fig. 23 in the paper shows a slight increase of stress at the deck edge and a very considerable decrease of stress near the centre line. This is not what one would expect from shear lag. One would expect shear to give a peak at the deck edge and a gradual falling-off of stress towards the middle.

Mr. B. N. Baxter: The results show that the simple beam theory does give correct values for the mean stresses, but underestimates stress values at the deck edge and overestimates them at the deck centre.

Referring to the first of the longitudinal stress distribution plots, the stress at the deck edge, using the simple beam theory, is 4 tons per square inch. The additional stress as calculated by the shear lag theory I find to be 0·17 ton per square inch, an increase of about 4·3 per cent, and the mean stress as measured by the gauges is about 5·6 tons per square inch, when extrapolated to the deck edge, an increase of 40 per cent. This indicates that the additional stress due to shear strain in such a structure is not important.

I would like to know whether the authors found the electric resistance strain gauges to be as satisfactory as the acoustic strain gauges, and if there was any trouble due to zero drift.

Mr. A. J. Merrington: The authors state that after collapse there was no evidence of rivet slip, and I ask whether, before that stage was reached, there was any evidence of overstraining at the joints. When designers plan for very high working stresses it is not unknown that difficulties arise at sea during very prolonged periods of heavy weather. During the war some cruisers, which did extremely heavy service in the North Atlantic, gave trouble in their double bottoms. In the trials described was there any evidence of that stage arising before the 17 or 18 tons per square inch collapsing stress was obtained? I suppose it would show in the upper deck, and Dr. Livingston Smith's suggestion that the trials might have been carried out under sagging conditions might have given more information from the point of view of the working conditions in a ship subjected to prolonged heavy strain.

Would the authors give the results of the calculations for the standard tests, namely, putting a ship on L/20 wave, as that will give an interesting comparison of design stresses compared with the stresses applied on the trials?

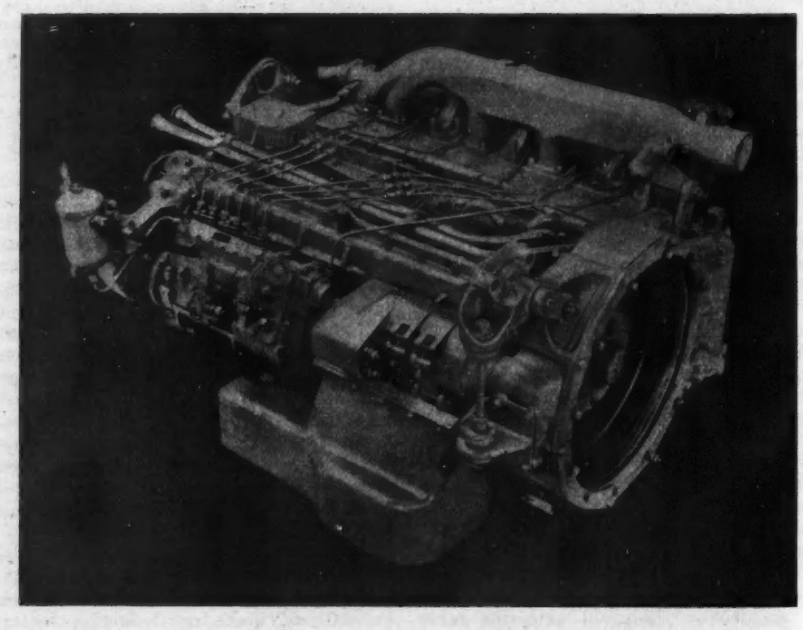
*(To be continued)*

# A Multi-Engined Six Coach Diesel Train

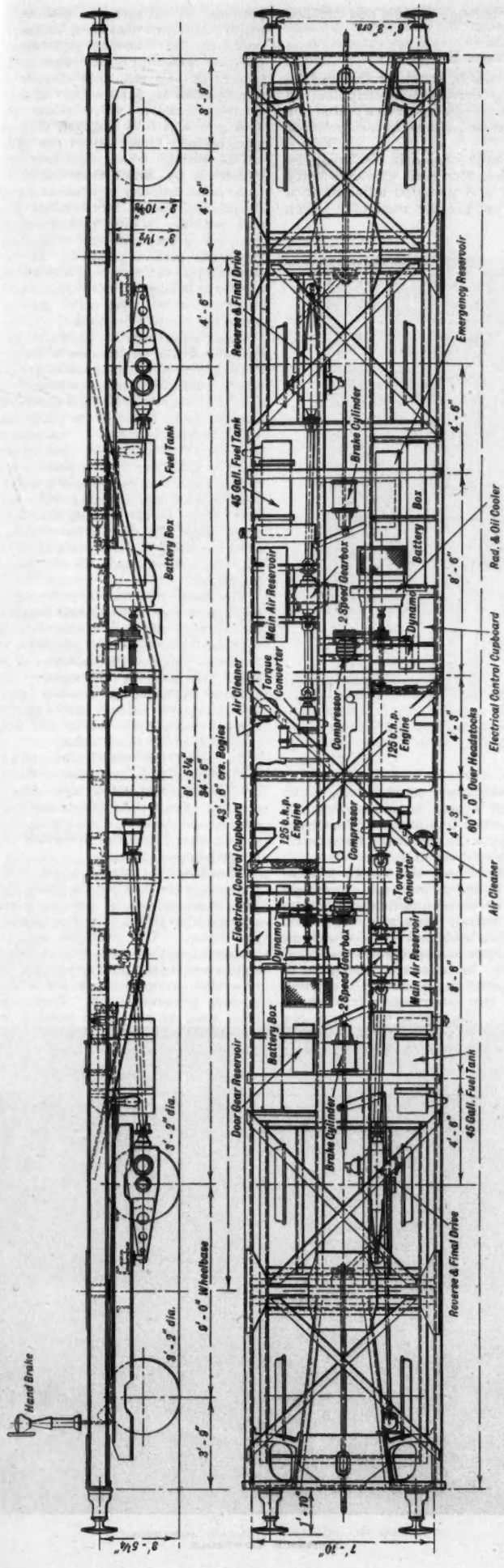
*An interesting new six-coach train, which is the first of seven similar trains, has been placed in service on the Belfast-Bangor line of the Ulster Transport Authority. Each of the four power coaches of this train has two horizontal 125 b.h.p. diesel engines, driving the axles through hydraulic torque converters and gearing. All the engines on the train are arranged to run at four set speeds, and control gear has been developed to engage these speeds simultaneously throughout the train.*

SINCE the formation of the Ulster Transport Authority in 1948 its chief engineer, Mr. James Courtney, and his technical staff have carried out extensive research into the most economical method of utilising the modern diesel engine to meet the requirements of general passenger train services on the lines operated by the authority. Experience of diesel railcar operation on the N.C.C. system indicated that the use of coupled powered railcars with non-powered intermediate coaches had several advantages. When towards the end of 1948 British vehicle manufacturers introduced a horizontal diesel-engined bus, immediate advantage was taken by the U.T.A. to test the possibility of incorporating this flat engine as the propelling unit in existing types of railway coaching stock. An experimental train, consisting of three coaches and using these engines, was built and placed in service last August on the Belfast-Bangor line, a distance of 12¼ miles. This train has four A.E.C. flat diesel engines, two each on the leading and rear coaches, with a non-powered intermediate coach. It proved that the running costs, as compared with steam traction, could be considerably reduced, but the total carrying capacity of such three-coach trains was not sufficient to meet the overall demands of passenger schedules on any section of the Authority's railway lines. Investigations were continued and a further development in the use of multi-engine drives for rolling stock was brought about by the pooling of the technical resources of Leyland Motors, Ltd., Walker Brothers (Wigan), Ltd., and the engineering department of the Ulster Transport Authority. As a result of this work equipment has been developed whereby the controls of eight Leyland flat diesel engines on a train can be operated simultaneously. These engines, giving a total output of 1000 b.h.p., are capable of propelling a train of six to eight coaches, having a gross weight of 185 to 225 tons, at 73 m.p.h. over average rail track formation. The design developed is thought to be the first application of the use of multi-powered diesel coach units to such an extent in rail traction. The control system allows a driver to start or stop any engine from his cab, and gives him full visual indication whether each engine is stopped or running whilst the train is travelling.

Based upon these developments, a six-coach train with multi-power units was built in the Authority's workshops at Duncrue Street,



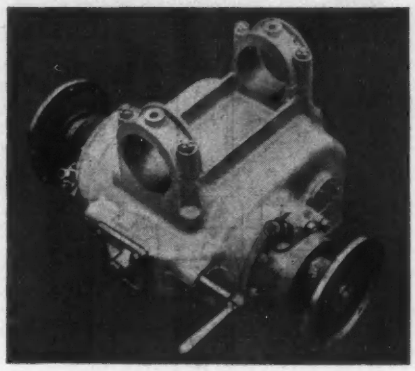
125 B.H.P. HORIZONTAL DIESEL ENGINE




ARRANGEMENT OF DIESEL ENGINE POWER UNITS IN UNDERFRAME

Belfast, from existing coaching stock. It consists of four powered coaches and two non-powered intermediate coaches and is so designed that, in order to give flexibility of service, it can be split up into smaller combinations for use during the off-peak periods of the day. The total seating capacity of the six-coach train consists of 48 first-class and 336 standard-class seats, and ample luggage space is available.

The Belfast-Bangor branch, has a double line and a minimum of goods traffic, and there is a comparatively dense population along the route, which makes it well suited to be completely operated by multi-engine trains, and it is estimated that in order to give a high frequency of service seven six-coach trains will be required. It is proposed to provide the remaining six six-coach trains by using



AUXILIARY GEARBOX

ten standard carriages and constructing twenty-six new vehicles. Eighteen of the new vehicles will be of lightweight steel construction of integral design, and the remaining eight will consist of lightweight bodies built on standard underframes which the Authority already have in stock. The design and fabrication of the integral vehicles and the lightweight bodies have been carried out by Metal Sections, Ltd., Oldbury, Birmingham, and the final assembly will be completed in the Authority's workshops.

The leading particulars and general data on one of the new powered coaches are given in the following table.

*Leading Dimensions*

| | |
|---|---|
| Gauge | 5ft 3in |
| Bogie wheel base | 9ft |
| Bogie centres | 43ft 6in |
| Diameter of wheels | 3ft 2in |
| Length over headstocks | 60ft |
| Length over buffers | 63ft 8in |
| Total length of six-car train | 382ft |
| Width of body | 9ft 5½in |
| Height over roof | 12ft 4¾in |
| Estimated weight of powered coach (conversions) | 36 tons (tare) |
| Estimated weight of intermediate coach (conversions) | 30 tons (tare) |
| Estimated weight of powered coach (integral) | 26 tons (tare) |
| Estimated weight of intermediate coach (integral) | 20 tons (tare) |
| Fuel capacity | 90 gallons |
| Engines : Leyland six-cylinder, horizontal, direct injection | |
| Cubic capacity | 597 cubic inches |
| Maximum torque | 410 lb-ft at 900 r.p.m. |
| Brake horsepower | 125 at 1800 r.p.m. |
| Governed speed | 2000 r.p.m. |
| Final drive ratio | 4·016 : 1 |

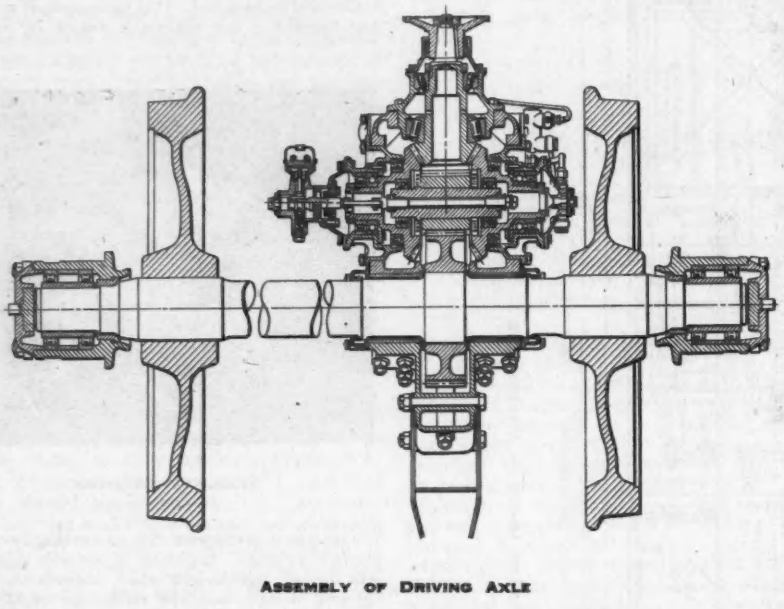
*Tractive Effort*

| | |
|---|---|
| High gear ratio : | |
| Converter drive | 37,610lb |
| Direct drive | 5,760lb |
| Low gear ratio : | |
| Coverter drive | 37,000lb |
| Direct drive | 7,700lb |

The first of the six-coach diesel trains is, as already stated, composed of converted centre corridor bogie carriages and comprises four twin-engined powered coaches and two non-powered intermediate coaches. The arrangement of the plant and controls of all powered coaches is identical and the coaches are designed for indiscriminate coupling, the only essential in the make-up of the train is that there must be a driving position at each end. As can be seen from the drawing we reproduce, all the

power plant is accommodated in the underframes, leaving the entire floor area free for seating, luggage space and the driver's control cabs, there being only one control position in each powered coach.

Two Leyland 125 b.h.p. horizontal diesel engines are used on each powered coach, the transmission units being made by Walker Bros., of Wigan, and Leyland Motors, Ltd. The layout of the power and transmission units in the underframes can be seen in the accompanying drawings and photographs. The two flexibly suspended engines of a vehicle are arranged symmetrically on each side of the longitudinal centre line, each engine driving the inside axle of one bogie.



ASSEMBLY OF DRIVING AXLE

The drive from each engine is taken through a Lysholm Smith (Leyland) torque converter and short universally jointed propeller shaft to an auxiliary gearbox, and thence by a similar propeller shaft to the final drive on the axle.

The torque converter is of unit construction with the engine and is fitted with a double-acting clutch having a neutral position. The toggle mechanism of this clutch is operated by a double-acting air cylinder. The hydraulic portion of the torque converter consists of a centrifugal pump in a single casing with a three-stage hydraulic turbine, which gives a maximum torque multiplication of 5 to 1.

A tubular member supports the auxiliary gearbox arranged in the transmission between the torque converter and the final drive box. This gearbox provides a high gear ratio of 1 to 1·328 and a low ratio of 1 to 1 for long or short-distance working. Changing from one gear ratio to another is effected manually at the box. With the low gear ratio the maximum train speed is 55 m.p.h., and with the high gear ratio 73 m.p.h.

The double reduction and reverse final drive, which is shown in one of the drawings, comprises a bevel pinion in constant mesh with two bevel gears. These bevel gears have internal spur teeth. The layshaft incorporates a spur pinion, the teeth of which mesh with one or the other set of internal teeth of the bevel gears and so determine the direction of rotation. Also in constant mesh with the spur pinion is a second spur gear pressed on to the driving axle.

The radiator fan located in front of the engine is driven by a short propeller shaft on which pulleys for driving the electric generator and air compressor are mounted. This compressor supplies the air for all the controls, braking and power-operated door equipment. Each radiator is built in three sections, one section for the engine cooling water, the second for engine oil cooling, and the third for the torque converter fluid. Cooling air for the radiators is drawn from a high level through ducting and expelled on to the track.

### Control Equipment

All the train controls are electro-pneumatically operated, the current being supplied by two 24V, 222Ah capacity batteries situated one on each side of the underframe in each powered coach.

The speed of each engine is controlled by small air cylinders, four such cylinders being built into a unit and mounted adjacent to a butterfly valve on the air manifold. Each engine has its own speed control unit, which gives four engine speeds in addition to the normal idling speed. One group of four magnetic valves supplies the air for the two control units in each powered coach.

As already mentioned, the clutch is controlled by an air cylinder built on to the torque converter and three clutch positions are obtainable, namely, neutral, converter drive and direct drive. Air is admitted to the clutch air cylinder through two magnetic valves adjacent to each converter. In order that the speed of the train may exceed the speed of the engines, when necessary, two overrunning free wheels are incorporated in the torque converters, one for the converter drive and one for direct drive.

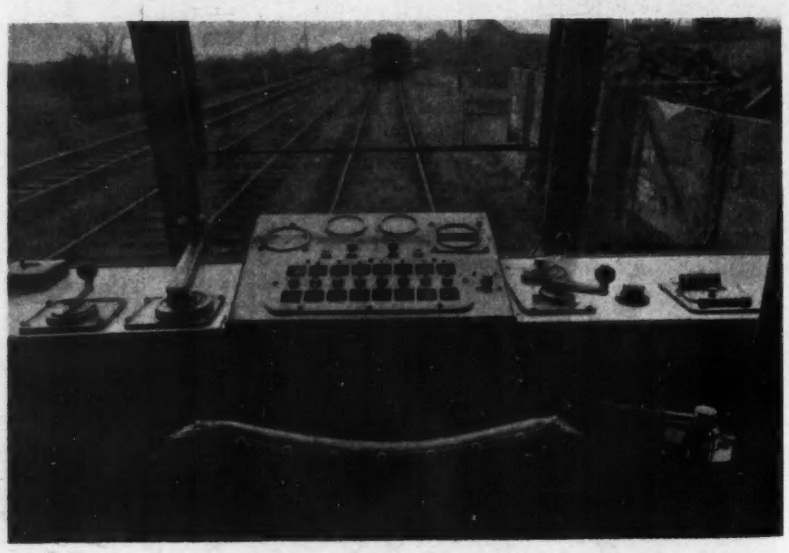
Forward or reverse direction of train travel is obtained by air-actuated pistons in cylinders mounted on each final drive housing, the pistons operating the "forward and reverse" sliding pinions. The supply of compressed air is controlled by two electro-pneumatic valves, and two switches are fitted to cut off the feed to the electro-pneumatic valve when the layshaft spur pinion is fully engaged with the internal spur teeth. These valves are arranged in a circuit, through which the driver is given a clear indication by lamps that the sliding pinions have been properly positioned for the desired direction of travel. In the event of a "forward and reverse" sliding pinion creeping out of gear, air is automatically re-applied to restore it to the correct position. If, however, for some reason the reversing mechanism, is faulty on any axle and will not respond to the driver's selector switch, that drive can be manually set in the neutral position.

Other safeguards are employed in the control system. If the oil pressure of an engine should drop below a predetermined figure or if the water level in the radiator header tank should fall below safety level, that particular engine is automatically stopped by an isolating switch and its clutch returned to the neutral position. The driver is warned of this by an indicator lamp on the control panel, and the starter of the engine cannot be re-engaged until the fault has been located and rectified. The advantage of this safety device is that, should the trouble occur while the train is in motion, the driver need not bring the train to a halt, but can continue to his destination on the remaining seven engines.

The starting current for each engine and other controls in any one powered coach comes from the battery of that coach, but the current required to energise the relays for each unit is fed from either of the batteries in the powered coach occupied by the driver. The control circuits in adjacent coaches are connected by multicore cables and twenty-seven-way jumper receptacles which are fitted to the underside of the headstocks.

To assist the maintenance staff the local control panels, shown in one of the illustrations, are provided at each side of the powered coaches. From these points the engines can be started and stopped, the working of the isolating switch tested and the operation of the clutch observed.

The driver's controls, apart from the brake controls, were supplied by Sharp Control Gear, Ltd., and consist of electric switches which operate the various magnetic valves throughout the train. The switches are conveniently grouped together on a control table, which, as can be seen in the photograph we reproduce on this page, occupies the width of the cab front in each powered coach. These controls have been kept as simple as possible and are for engine speed, clutch, and direction control. The engine speed is controlled by a handle on



DRIVER'S CONTROLS

the driver's left hand and it gives any one of the pre-set four engine speeds simultaneously to all the engines throughout the train. A "dead man's device" is incorporated in this unit and, should the driver unconsciously release the handle whilst the train is in motion, all the engines are returned to idling speed, the clutches are automatically returned to neutral and, after a five seconds' delay, the brakes are automatically applied. The return of the clutches into neutral prevents the stalling of the engines.

The clutch control has five positions, i.e., handle off, neutral, converter drive, direct drive, and a test position. Only with the handle in neutral position is it possible to start the engines or change the direction of the train. The test position is provided for the benefit of the maintenance staff. The direction control has two positions only—forward and reverse.

In addition to the direction indicating lights, the driver's instrument panel has the following control and indicating equipment — eight engine start buttons, eight engine stop buttons, eight engine stop indicator lights, two revolution counters and speedometers, one single air pressure gauge for indicating the pressure in the main reservoir, one duplex air pressure gauge for indicating the pressure in the emergency pipe and brake cylinder pipes, and an air horn button. Shunting controls also provided at each side of the driver's cab consist of engine speed controllers, which give two speeds only and are operative only in converter drive. The feed to all the controls is effected by an interlocking control switch situated on the table. Movement of this handle to the left or right selects either battery in that powered coach to feed the control system, and by removing the handle to either position the control switches in all other drivers' compartments in the train are locked and no unauthorised person can interfere with them. There are also shunting brake valves in addition to the main brake valve. While shunting, the "dead man's device" in the main engine speed control is neutralised by the driver depressing a conveniently placed button. A hand brake wheel is also provided in the driver's compartment for parking purposes.

### Braking Equipment

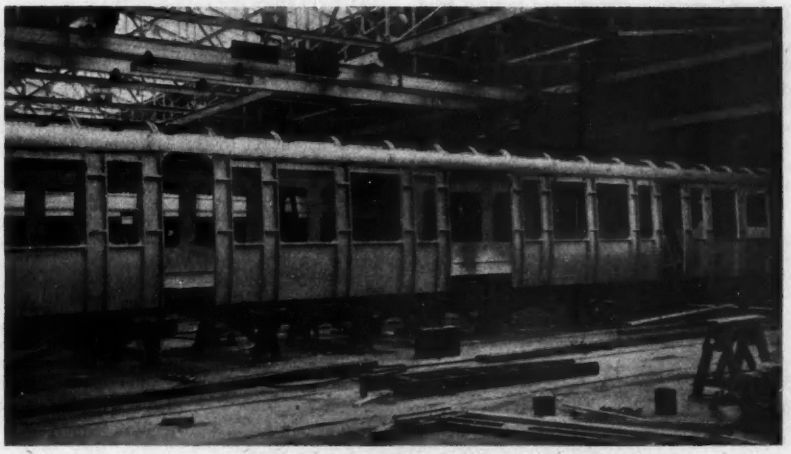
Air for the braking system is supplied by two 25 cu. ft compressors, belt driven from the engines, and is stored at 100 lb per square inch in two main reservoirs in each powered coach with a supplementary reservoir in the intermediate coaches.

Superimposed on the Westinghouse straight air brake system fitted is electro-pneumatic application equipment designed to give simultaneous application throughout the train.

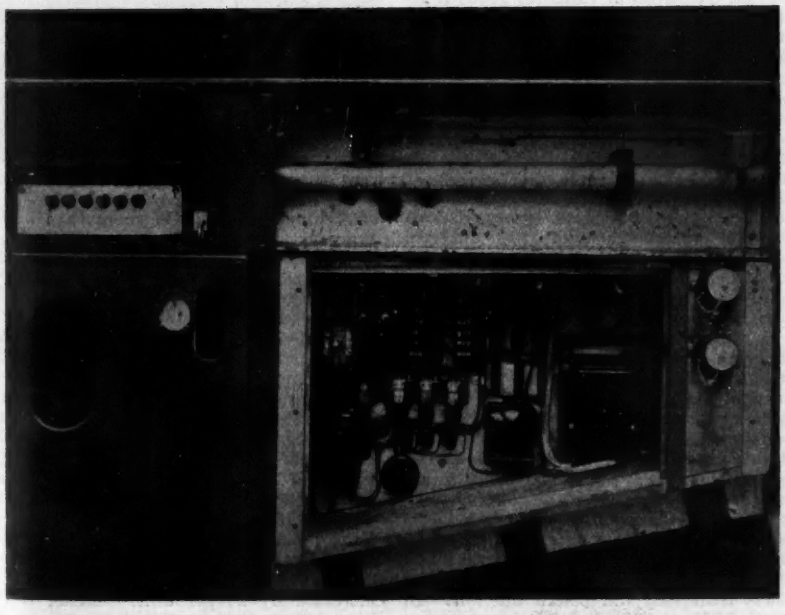
An emergency brake which is controlled by the driver's brake valve operates on a reduction of pressure in the emergency pipe which is fitted throughout the train. Emergency brake applications can also be made from the engine speed controller or by the use of the passenger emergency valves, or in the case of a breakaway. When the emergency pipe is vented and the emergency brake is applied, the control governor connected to the emergency pipe opens the electrical circuit to the engine speed controller and makes another electrical circuit, which brings the engines to idling speed and the clutch to neutral position. The shunting brake valves apply the straight air brake only on the powered coach from which the driver is operating.

The problem of economically heating multi-unit coaching stock with diesel traction has been successfully overcome by using the engine cooling water in the powered coaches and slow combustion hot water boilers in the intermediate coaches. For heating the powered coaches there are two separate open-circuit systems, the cooling water of each engine supplying heat to one-half of the coach. When an engine reaches its normal running temperature a thermostat opens and the hot water is pumped through gilled tubes along the sides of the coach. If the water temperature on the return is too high, another thermostat opens and allows it to pass through the radiator before finally returning to the engine. Suitable cowls are provided over the gilled tubes to promote air circulation and to prevent passengers from coming into contact with the hot tubes.

The non-powered intermediate coaches are heated by means of a hot water convection system. In the centre of each coach there is a hot water boiler, fired with either coke or anthracite. The base of this boiler and fire bed are well below the top of the underframe, and the boiler is set in a small compartment lined with fireproof material. Hot water from the boiler is piped along the centre line of the underframe and upward through branches to a series of gilled tubes running along each side of the coach. In the flow pipe from the boiler is fitted a thermostat, which is mechanically connected to the flue damper. When the water reaches a predetermined temperature the damper is partially closed and combustion retarded. The make-up tanks for the heating systems are mounted in the roofs and can be filled from the track level.



LIGHTWEIGHT COACH UNDER CONSTRUCTION



CONTROL CABINET ON SIDE OF COACH

### Coach Bodies

The coach bodies converted for the construction of the first train are composite open vestibule vehicles. The conversion to powered coaches entailed the removal of existing seating, lavatories and centre transverse partitions, and required the building of a shaped end to form the front of the full width driver's compartment. Three large windows give the driver an unobstructed view of the track and signals, and two existing hinged doors give access from the outside to the driver's compartment.

Two powered coaches in the six-coach train are each divided into a driver's compartment, a first-class compartment, two separate standard class compartments, with a guard's and luggage compartment at one end. The other two powered coaches have an additional compartment in place of the guard's compartment. Some structural alterations to the sides of the carriages had to be made to provide these compartments and give an equal distribution of seating space. Entrance and exit from the coaches is by means of power-operated sliding doors, double doors being fitted at the large central vestibule and the guard's compartment. The outside sliding doors are operated by long-stroke air cylinders mounted in spherical bearings above each doorway, two such cylinders being employed for the double doors. Low-pressure air for door operation is obtained from the braking system, the pressure being controlled at 40 lb. per square inch by means of a reducing valve.

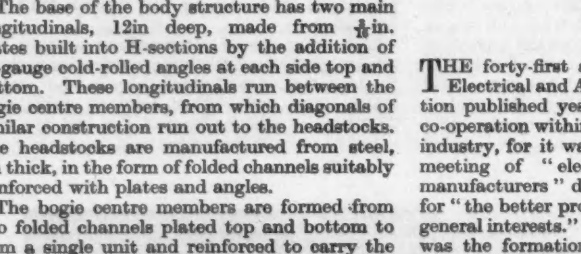
### New Lightweight Steel Trains

As mentioned above, a number of the vehicles for the remaining trains are being constructed in lightweight steel of integral design. These

vehicles will be equipped with propelling units, transmission and other equipment similar to the train described. In these lightweight coaches the entire body has been designed as a load-carrying structure.

The base of the body structure has two main longitudinals, 12in deep, made from $\frac{1}{16}$in. plates built into H-sections by the addition of 14-gauge cold-rolled angles at each side top and bottom. These longitudinals run between the bogie centre members, from which diagonals of similar construction run out to the headstocks. The headstocks are manufactured from steel, $\frac{1}{4}$in thick, in the form of folded channels suitably reinforced with plates and angles.

The bogie centre members are formed from two folded channels plated top and bottom to form a single unit and reinforced to carry the bogie centre and side friction blocks. Cross members constructed in the same manner as the longitudinals, but with plates and top hat sections above and below the H-section, intersect the longitudinals at four places and connect the side soles together. The side soles are made



FINAL DRIVE MOUNTED ON AXLE

from $\frac{1}{4}$in steel formed into channels 6in deep and the cross members are tapered at the outer ends to suit the depth. None of the longitudinals forming the base of the structure is more than 12ft long, staggered joints being arranged and reinforced where necessary, and all solidly riveted together. Self-contained buffers and standard draw gear will be provided.

Corrugated 16-gauge steel flooring is riveted to the top of the base members, and in order to isolate as far as possible engine and track sounds from the interior of the coach, the floor will be covered with an ample thickness of cork. The body pillars, light rails and cantrails are of a special 14-gauge channel section. The bottom of the pillars and the 14-gauge truss panels, which are continuous from doorway to doorway and extend downwards from the waist rails, are solidly riveted to the side soles. In order to prevent racking of the quarters, steel panels are riveted to the inside of the framing from the waist line up to the cantrail.

The roof sections and Z-section purlins are fastened to the cantrails with angles. Continuous truss panels on the outside and truss panels above the doorways on the inside are riveted to the cantrails, the carlines and the first roof purlin, which is a channel section similar to the pillars. This method of construction, together with the roof panels, which are solidly riveted to the roof sections, give the necessary stability to the body structure.

All exterior panels are of aluminium alloy and are pop riveted to the structure, the panels below the waist being of a special ribbed section to prevent drumming.

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REFINERY IN VENEZUELA.—A lubricating oil plant with an annual output of 100,000 tons has been completed at a cost of £8,000,000 at the Cardon Refinery of the Shell Petroleum Company, Ltd., on the Paraguana Peninsular, Northern Venezuela. The plant consists of the following units: propane de-asphalting, furfural extraction, M.E.K./benzol dewaxing, and clay contracting. The present intake of the refinery is 5,000,000 tons per annum and this will rise to 8,500,000 tons by 1953.

# The British Electrical and Allied Manufacturers' Association

THE forty-first annual report of the British Electrical and Allied Manufacturers' Association published yesterday, marks fifty years of co-operation within the electrical manufacturing industry, for it was in 1902 that a preliminary meeting of "electrical supply houses and manufacturers" decided to form an association for "the better protection of their financial and general interests." The outcome of this meeting was the formation of the National Electrical Manufacturers' Association, which, with its twenty-nine members was the forerunner of the BEAMA.

In its review of the year 1951–52, the report draws attention to the industry's achievement in exporting electrical goods valued at £189,000,000, an increase of 20 per cent over the previous year. This increase was shared by most sections of the industry—in particular by the makers of domestic electrical appliances, the exports of which increased by £10,500,000.

Commonwealth countries again provided the main market for British electrical equipment, and they took about three-fifths of this country's electrical exports. Australia was the largest single customer. Partly because of the high prices of her primary products and partly because of her investment in manufacturing plant, she bought from Great Britain electrical machinery and apparatus totalling nearly £30,000,000, an amount which has never been exceeded by any single country. An important part (£3,000,000) of Australia's electrical imports consisted of domestic appliances, particularly washing machines.

Canada's imports of electrical goods from the United Kingdom rose by more than 50 per cent compared with 1950, and were worth nearly £7,000,000. Thanks to the efforts of BEAMA firms to develop the North American market, Canada was second only to Australia as a buyer of British generating plant.

Among the European countries that bought substantial quantities of electrical goods from Great Britain were the Netherlands, Belgium, and the Scandinavian countries, and domestic appliances figured prominently in their purchases.

Electrical exports to South America were maintained; Brazil was the largest single customer, while purchases by the Argentine fell, reflecting the difficulties of Great Britain's trade with that country.

Discussing future prospects for British electrical exports, the BEAMA report refers to the possible repercussions of this country's import restrictions, on the one hand, and the effects of her efforts to restore the stability of sterling, on the other. In any case, a great deal depends on whether a high level of economic activity can be maintained in the United States. In this connection, the reference made in the report to world trade in electrical products is interesting. It is stated that, according to a preliminary estimate, the exports of the main electrical manufacturing industries of the world totalled about £625,000,000 in 1951, which is more than eight times the corresponding figure for the 1930s.

Because of the disruption of the economies of the former enemy countries, the United Kingdom and the United States take a much larger proportion of world trade in electrical products than they did before the war. In 1935, the U.K. and the U.S.A. taken together were responsible for much less than half of the total electrical exports. In 1951 their share was 62 per cent. The report goes on to point out that the totals of the electrical exports from the U.K. and the U.S.A. are roughly of the same order of magnitude and have been so since 1948.

Nevertheless, according to the report, strong competition is to be expected, particularly from Germany. That country has made remarkable progress in the past three years. In 1949 her electrical exports were negligible, but in 1951 they had reached nearly one-third of Great Britain's. This growth was probably assisted by the ability of German exporters to offer shorter deliveries and by the direct incentive of profits tax relief offered by the Bonn Government.

Japanese competition, according to the report, has been strongest in India (Britain's third largest customer for electrical goods) and in Pakistan. Elsewhere, reports of orders for electrical machinery being lost to Japan have been fewer during the past year. One of the reasons is that, because of increased costs of raw materials, Japan has had to quote prices no lower, generally, than our own. At the same time, Japan's production has been hampered by shortage of electrical power.

Referring to the prospects for exports to Canada in particular, the report refers to encouraging signs that a growing increase in exports is foreshadowed by the volume of orders secured by member firms, but not yet executed. One manufacturer, for example, has a contract for traction equipment on the "Underground" Railway now being built for the Toronto Transportation Company. Another firm has obtained, in the face of strong competition, an extensive order for generators and transformers for the Aluminium Company of Canada. The transformers are thought to be the highest voltage transformers ordered from Great Britain and will be among the largest three-phase banks in North America.

Plant due for delivery includes turbo-generators for the Hydro-Electric Power Commission of Ontario. At the same time, Southern Ontario's change of frequency scheme has given effect to useful orders for transformers and electric motors.

On the subject of raw materials, the BEAMA report states that the worsening in the supply of materials which was noticeable a year ago has continued. Under new control orders for copper, zinc and its alloys, and for nickel, the manufacture of certain end products has been prohibited for home sales.

The manufacture of generating plant (over 10MW) during the year under review totalled 1785MW, which was shared almost equally between home and export markets. Generating plant of small and medium size totalled 223MW, including 115MW for overseas. During the year the British Electricity Authority commissioned 1235MW of new plant (1113MW sent out), which was 150MW more than in 1950. Many large generating units were installed, but could not be commissioned because of delays involving essential parts of allied plant.

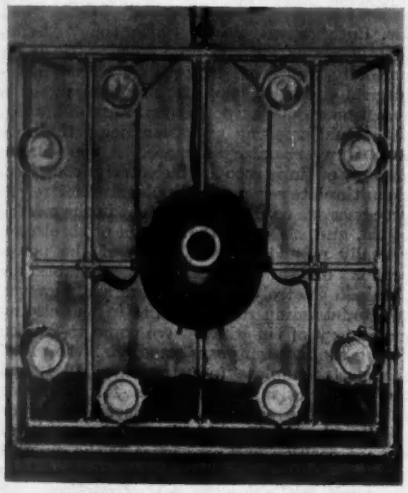
A substantial part of the report is concerned with the work of the council committees, the technical committees and the BEAMA sections. In the latter it is stated that domestic sales of arc welding electrode in 1951 were 36 per cent above those for 1950, but that the growth of export sales was hindered by lack of electrode core wire, which affected about 70 per cent of export orders. The sales of arc welding plant were well maintained at home, being 25 per cent more than in 1950, thanks mainly to the widespread use of arc welding in the new oil refinery installations and to the gradually increasing demands of the rearmament programme. Compared with 1950 export sales increased by 26 per cent. Similar increases were recorded in the demand for resistance welding machines.

# Underwater Television

NEARLY a year has passed since underwater television was used for the first time, when the wreck of the submarine "Affray" was identified. Since then the development commercially of equipment for underwater television has been the subject of a good deal of work by Marconi's Wireless Telegraph Company, Ltd., in conjunction with Siebe Gorman and Co., Ltd. Last week the progress that has been made was demonstrated at the Tolworth works of the latter company, and we were able to see the underwater television equipment in operation in a test tank.

For underwater work the television camera is enclosed in a pressure casing mounted on an adjustable tubular gantry, which also carries eight 150W tungsten filament lighting fittings, as illustrated herewith. The steel pressure casing, which was designed and made by Siebe Gorman and Co., Ltd., is a cylindrical vessel, 28in diameter by 34in, with a domed end, pressure tested under a static head of 650ft. The optical glass window in the equipment demonstrated is pressure tested under a static head equivalent to 350ft of water; but there is, of course, no reason why the casing should not be designed for operation, if required, at depths of the order of 1000ft. The circular rear cover carries the camera and cable entry and is secured to the cylindrical casing by thirty-two bolts.

The television camera itself is an "Image Orthicon" equipment similar to that used for outside broadcasts, but modified particularly to allow the focusing and iris controls to be remotely controlled from the parent ship. Remote focus control operates through a rack and quadrant driven by a fractional



UNDERWATER TELEVISION CAMERA RIG

horsepower motor, which tracks the "Image Orthicon" tube relatively to the lens. Remote control of the iris diaphragm allows the lens aperture to be varied to produce the best picture obtainable under conditions of considerable variation in lighting.

With both focus and iris controls remote indication is provided on a small control unit, which is operated on the parent ship. One advantage of the focus indication is that the scale of the indicating meter can be calibrated to allow deductions to be made as to the size of an object and its distance from the camera lens.

The mounting rig illustrated herewith allows the pressure vessel containing the camera to be tilted on its trunnions at varying angles from the horizontal to vertically downwards. Similarly the inclination of each of the eight lamp fittings can be varied to produce the desired lighting conditions. Adjustments of lamp and camera tilt can, of course, only be made manually when the equipment is on the ship. There is, however, an inclinometer incorporated in the camera: it consists of a free pendulum, which, in conjunction with a potentiometer, gives a remote indication, on the control panel, of camera tilt. Finally, there is a water indicator, whereby the operators are given warning of any moisture that may enter the casing. The wetness indicator is a simple device consisting of a strip of blotting-paper, which forms part of an alarm circuit operating at 250V. This "detector" is placed in the bottom of the pressure casing, where it will absorb any moisture that may be

UNDERWATER TELEVISION CAMERA

admitted; when the resistance of the strip falls to about 60,000 ohms it causes a neon lamp to light and any further fall in resistance causes an alarm bell to ring. If required, a remote bearing compass can be fitted to show the orientation of the camera in operation on the sea bed.

The camera control unit mentioned above is a small panel suitable for operating on a desk. It embodies instruments to give remote indication of focus, aperture and inclination. It also carries the start and stop switches for the motor drives that control the focus and iris aperture respectively. In addition, the lighting system is controlled from the panel by switches whereby the lamps can be switched on or off in pairs.

The picture transmitted by the television camera is presented on monitor equipment, which is a part of the normal television chain. The main difference compared with the standard equipment is that the display raster is on 625 lines, instead of the B.B.C.'s 405 lines.

Connection between the camera control unit and the submerged camera equipment is provided by a camera cable which consists of the normal cable with the addition of an outer sheath of 0·1in p.v.c., tested for an equivalent depth of 1200ft. The cable enters the pressure vessel through a gland consisting of a solid rubber muff with a tapered hole and a flange which is clamped to the back of the cylindrical casing by a plate secured by two rows of six and eight nuts respectively.

Inside the pressure vessel the cable terminates on a thrust block, which resists the external water pressure. The various leads are brought out radially on to the terminal block, which forms a sandwich with the thrust block. Leads for the remote controls are taken from this terminal block to a terminal block on the side of the camera and by this arrangement the internal wiring of the camera is disturbed as little as possible.

The demonstration was arranged with the help of a "frogman" to show the performance of the equipment. The pictures obtained with object distances of 6ft to 12ft from the camera under various lighting conditions were of good quality with sufficient detail to permit of the identification of small objects such as the brand of a packet of cigarettes.

## Indian Engineering News

*(By an Indian Correspondent)*

### Bombay Water Supply

The first important phase of the Bombay Municipality's £12,000,000 project to augment the city's water supply—driving of three tunnels of an aggregate length of 20,500ft—was completed on April 5th, a few weeks ahead of schedule. The tunnel work, started on February 2nd, is one of the three major items of the five-year Vaitarna-cum-Tansa scheme, the others being the construction of a 1820ft long and 269ft high dam across the Vaitarna River, and the laying of a 10ft diameter pipe-line between Vaitarna and Tansa (6¼ miles long), and an 8ft pipe-line between Tansa and Mahim, a distance of 54½ miles. The contract for boring tunnels was undertaken by two Indian firms at a total cost of over £1,000,000 sterling and the labour force was just over 1000. During the ceremony held to celebrate the completion of the tunnel work, the Bombay State Home Minister laid special emphasis on the fact that the technical staff was entirely Indian and that the whole task was completed without recourse to any "foreign experts."

### Railway Link

A link in the communications with the Kangra, Kulu and Kashmir valleys was established when the 27-mile-long Mukerian–Pathankot broad-gauge railway was opened to passenger traffic by the Union Minister for Railways and Transport on April 7th. Constructed at a cost of Rs.3.77 crores (£2·83 million) in the course of two years, this new line, taking off from the existing railhead at Mukerian, constitutes a saving of 44 miles over the existing route between Delhi and Pathankot via Amritsar. It follows a south-north alignment, passing through the Hoshiarpur, Kangre and Gurdaspur districts of the Punjab to get to Pathankot, gateway to the three picturesque and fertile valleys. The line includes a railway bridge across the Beas River consisting of fourteen spans of 150ft each, built at a cost of Rs. 1·46 crores (£1·1 million).

### Hirakud Dam Project

The Hirakud dam project, whose slow execution has aroused criticism from both the public and the technical Press, was recently a subject of inquiry by the Union Government, and in consultation with the Orissa State Government, a Hirakud Control Board and a Hirakud Development Board have been established with a view to ensuring efficient, economical and early execution of the project. The Control Board will be in overall charge of the project, including its technical and financial aspects under the general supervision of the Government of India in the Ministry of Natural Resources and Scientific Research. Similar action may also be taken with regard to other great River Valley schemes begun, without thorough preparation, in the wake of post-independence enthusiasm.

# Metallurgical Topics

## Electro-Metallurgical Industry

A SYMPOSIUM on "Electrolytic Processes in Chemical and Metallurgical Industry," organised by the London Section of the Society of Chemical Industry, was held at University College, London, on April 7 and 8, 1952. The programme was largely metallurgical and several of the papers contained information of recent developments and new products which may be of interest to engineers. In an introductory address, Dr. H. J. T. Ellingham outlined the principles on which all electro-chemical processes depend, and indicated how, on thermodynamic grounds, the possibilities of success in electro-metallurgical extraction processes could be foreshadowed. He indicated by reference to the periodic table the groups of elements which could be extracted by electrolytic reduction from molten salts or by deposition from aqueous solutions, either in the pure form or as alloys. Dr. Ellingham pointed out that it was a mistake to suppose that the amount of electrical energy required was necessarily large, making electrolytic processes suitable only in places where there was cheap power. The power consumption was frequently quite small, though it was interesting to note that the electro-metallurgical process which was most firmly established in Britain (namely, aluminium reduction) consumes more current than almost any other.

### Magnesium

The first paper, by Dr. A. L. Hock (Magnesium Electron, Ltd.), dealt with the "Electrolytic Extraction of Magnesium from Fused Salts." Dr. Hock recalled that exactly 100 years ago Bunsen prepared magnesium by the electrolysis of fused anhydrous magnesium chloride, and so initiated the process on which modern practice is based. The use of dehydrated carnallite (potassium magnesium chloride) was abandoned owing to the necessity of frequently cleaning out the cell. Present-day practice relies on continuous operation and is based on the addition of more or less anhydrous magnesium chloride to an electrolyte which varies in composition according to local conditions and economic circumstances. Such an electrolyte may contain 7 to 15 per cent of magnesium chloride with 20 per cent NaCl and 30 per cent KCl to increase conductivity and fluidity, and 40 per cent $BaCl_2$ to facilitate flotation of the magnesium to the surface of the electrolyte. Typical plant was illustrated by diagrams and a model, and possible trends in future design and operation of molten chloride cells were discussed, factors of importance in further development being improved methods of obtaining completely anhydrous magnesium chloride and of avoiding warping of grid cathodes, and the production of thin long-life partitions resistant to the action of chlorine.

### Aluminium

In introducing the next paper on the "Electrolytic Production and Refining of Aluminium," Mr. J. Waddington (British Aluminium Company, Ltd.) gave a lucid description of the Hall-Héroult process for the production of aluminium by the electrolysis of a solution of purified alumina in molten cryolite at about 970 deg. Cent., and of the various types of cell employed. A modern cell works at about 85 per cent current efficiency. Loss of metal occurs by the formation at the cathode of a metal or sub-fluoride "fog," which diffuses to the anode, where it is oxidised by the carbon dioxide formed there. If the aluminium content of the bath becomes very low, fluorine is liberated at the anode and there is a sharp rise in voltage. The condition of the bath is thus indicated, and when the voltage rises fresh alumina, which for preheating purposes has been placed to form a crust upon the bath, is stirred into the fused cryolite. The voltage required to operate a cell is always far higher than the decomposition voltage of alumina (1·7V), as much of the energy is dissipated as heat. A modern cell taking 40,000A at 4·7V produces 25 lb aluminium per hour, thus requiring 7·5kWh per pound of aluminium. The virgin aluminium produced in such cells may be 99·5 to 99·8 per cent pure, the chief impurities being iron, silicon and, to a less extent, titanium. A further 10kWh per pound of aluminium is required for the refining process to give super-purity metal (over 99·99 per cent pure).

So far the papers had dealt with modifications and improvements of well-established processes. On the second day they were more closely concerned with new fields of electro-metallurgical development. Dr. J. W. Cuthbertson (Tin Research Institute) spoke on "Recent Advances in the Electrolytic Extraction of Manganese, Chromium and Cobalt." He described how the growing demand for these metals, and their strategic importance, had stimulated research on their recovery from low-grade ores of the type that cannot profitably be treated by conventional smelting methods.

### Manganese

Some seventeen years ago the U.S. Bureau of Mines directed its attention to the possibility of extracting manganese from low-grade ores by electrolysis of a manganous sulphate-ammonium sulphate solution. Manganous oxide and carbonate are both soluble in a solution of ammonium sulphate and sulphuric acid; so, by appropriate choice of electrolyte, it was possible to devise a continuous process, using the spent electrolyte to leach the ore and so regenerate the cell feed liquor. Formidable difficulties were encountered, but final perfection of the process was achieved after several years as a result of further work by the Bureau of Standards and the Electro-Manganese Corporation. The output of the Electro-Manganese Corporation's plant at Knoxville, Tennessee, has grown from small beginnings to 8 tons a day in 1950, and further expansion is being anticipated. About 87 per cent of the metal in the ore is recovered for a total power consumption of 5·0kWh to 5·25kWh per pound. The current efficiency is given as 65 to 70 per cent. The metal produced has a purity of 99·97 per cent. It is the alpha (body-centred cubic) form of the metal, and, being brittle, it is marketed in the form of broken chips, about $\frac{1}{8}$in thick and varying in size. Summing up, Dr. Cuthbertson stated that, so far, the electrolytic production of manganese had only been operated on a large scale in America, where research and technical development of the process were still continuing. Moreover, the electro-metallurgical division of the Carbide and Chemical Corporation had announced its intention to build a plant of unstated capacity at Marietta, Ohio; but while this was evidence of definite expansion of the electrolytic process in America, it was doubtful whether conditions in Britain would be conducive to its adoption, and it was too early to attempt to predict future policy in this matter.

### Chromium

Dealing with chromium, Dr. Cuthbertson said that, for some years, it had been produced by a two-stage electrolytic process involving production of chromic acid and then its electrolysis. In the American process (based on the work of the Bureau of Mines, published in 1946) the metal was recovered by electrolysing a solution of purified chrome alum and sodium sulphate. The deposited metal contains 98·8 per cent chromium, the chief impurities being iron, sulphur, carbon, hydrogen and oxygen. The current efficiency exceeds 60 per cent or over three times that of the chromic acid process. As chromium is trivalent in the new electrolyte and hexavalent in chromic acid, the new process deposits about six times as much chromium per ampere-hour as the old one. Although commercial application had not yet started, it was significant that a new plant to operate the process was now under construction at Marietta, Ohio.

### Cobalt

In concluding his review of recent advances, Dr. Cuthbertson referred to cobalt, in the extraction of which electrolysis had played an increasingly important part. The electrolytic cobalt plant of L'Union Minière du Haut-Katanga, in the Belgian Congo, commenced operation in 1945, and has a capacity of 120 to 150 tons per month. The deposited metal contains 3 to 4 per cent of zinc and some basic sulphates, and is subsequently refined in an electric arc furnace. In the U.S. Bureau of Mines process, the electrolyte is an acid solution of purified cobalt sulphate obtained from the ore by an extensive roasting, leaching and precipitation treatment. The metal produced has a purity of 99·2 per cent and contains about 0·7 per cent of nickel. The current efficiency is 75 to 85 per cent with corresponding power consumption of 1·4kWh to 1·2kWh per pound, respectively.

Dr. Cuthbertson pointed out that in this case, as in all the recent advances dealt with, development would depend on many factors, and was likely to be confined, at any rate initially, to localities where suitable ores were available and where circumstances were such as to enable the new processes to compete economically with alternative methods of extraction.

### Tin

Dr. E. S. Hedges (Tin Research Institute) presented a paper prepared jointly with Dr. Cuthbertson, dealing with the "Electro-Metallurgy of Tin and its Alloys." Tin is not normally won from its ores by electro-metallurgical methods, though electrical power is sometimes used as a convenient form of heating, the actual smelting operation being the same as in a reverberatory furnace. A considerable amount of tin is recovered electrolytically from clean tinplate scrap and clippings. Electrolytic processes are used to some extent in the refining of tin, and, although the amount of tin electrolytically refined is small, some of the purest brands of tin commercially available are obtained electrolytically. There are, however, two outstanding developments in the electro-metallurgy of tin which have come to fruition during the last ten years or so, viz., the rise of the electro-tinplate industry since 1941, and the introduction of processes for producing alloys by the simultaneous electro-deposition of tin with other metals. Dr. Hedges reviewed the composition and properties of the different aqueous electrolytes from which tin had been deposited, indicating the field of application of each type.

### Electro-Tinplate

A comprehensive account was given of the principles of electro-tinplate manufacture, a development of the last ten years within which United States annual production has increased from 73,000 to 2,500,000 tons. The advent of continuous cold reduction of steel in the form of strip, in place of the pack rolling of sheets, led to investigation of the continuous electrolytic tinning of steel strip. Pilot plant was in operation in 1937, intensive development of manufacture followed in 1941–42 in the United States, where, within five years, there were twenty-five full-scale electrolytic lines, several more having been added in recent years. The first electrolytic line in Great Britain came into operation in 1947, two more are about to come into production, and the process has been taken up in other countries. The installations, which were described by Dr. Hedges as miracles of

electrical engineering, comprise a series of processing units all connected in tandem and running synchronously together. Coils of cold-reduced strip, 30in or more wide, are uncoiled and passed (at speeds varying from 600ft to 2000ft per minute) successively through degreasing and pickling tanks and the electro-tinning bath with intermediate water washes; then the plated strip passes through a radiant or high-frequency furnace or is heated by electrical resistance in order to melt the tin coating for a fraction of a second to brighten the plate; it is then generally lightly oxidised to improve lacquering quality by passing it through a chromic acid or other chromate bath, and finally it is oiled lightly by a mist of oil droplets. Afterwards, it is cut up into sheets of ordinary tinplate size. Details of four different electrolytes in use were given. On account of the high rate of relative motion between cathode and electrolyte, actual plating time is only a few seconds and high current density (200A to 500A per square foot) has to be used. Dr. Hedges emphasised that in spite of the high degree of efficiency already attained, many problems concerned not only with the electrodeposition process, but also with the preparation of the steel before plating, were still the subject of research.

### Tin Alloys

After referring to examples of alloy deposition which had been practised for a long time, Dr. Hedges briefly described three new processes, all due (it may be added) to the work of the Tin Research Institute. The first was the speculum plating process, whereby a copper-tin alloy containing about 42 per cent of tin may be plated directly on to steel, brass or copper, giving when polished a brilliant appearance closely resembling that of silver, and a good resistance to tarnishing in indoor atmospheres. The second was the production of tin-zinc coatings (usually containing 75 to 80 per cent of tin) for the protection of steel against corrosion. These coatings (unlike zinc) are easily solderable, and in electro-chemical behaviour the tin-zinc alloy resembles cadmium and has already been substituted for it in many applications. There were commercial plants for these two processes in many parts of the world. The most recent development was the production of a tin-nickel alloy, the first commercial plant in England coming into operation in 1951, and the first in the United States some months later. The alloy deposited corresponds to the intermetallic compound NiSn. It is very hard, does not scratch or wear easily, and has a remarkable range of corrosion resistance. It is a matter of interest that the compound cannot be obtained by cooling from the melt; such alloys of the same composition consist of a mixture of $Ni_3Sn_2$ and $Ni_3Sn_4$, and the electro-deposited alloy is converted into this mixture when heated for two hours at 300 deg. Cent.

### Electro-Chemical Industry

The remaining papers, presented at the last session of the symposium, were on the "Manufacture of Hydrogen Peroxide," by Mr. W. S. Wood (Laporte Chemicals, Ltd.), and on the "Electrolytic Production of Fluorine," by Mr. R. J. Kingdom (Imperial Smelting Corporation).

The good attendance at every session, and the discussions which followed the reading of each group of papers, were evidence of the interest aroused by the subject matter of the symposium.

## Carbonate Energisers in Pack Carburising

The factors which affect the well-known energising action of carbonates when mixed with charcoal for the carburisation of steel are still somewhat ill-defined, nor is the mechanism of their action completely understood. Important investigations carried out by R. A. Ragatz[1] in conjunction with M. Sutton and T. C. Fong led to the conclusion that both sodium and barium carbonates were powerful energisers and give results of the same order of magnitude. Sodium carbonate had a slightly greater effect at the high temperatures normally used in carburising, and had a definite energising effect at such low temperatures as 650–700 deg. Cent., whereas barium carbonate had practically no effect at these temperatures. Effectiveness varied with the nature of the carburising agent; for example, calcium carbonate was quite inert except when used in conjunction with metallurgical coke, barium carbonate was very effective except with retort carbon, while sodium carbonate was effective with all the seven types of carburising material employed.

If the reaction at the steel surface may be expressed by the equation $2CO+3Fe=CO_2+Fe_3C$, it is clear that anything which increases the concentration of CO and reduces that of $CO_2$ will accelerate carburisation. Fong and Ragatz considered that sodium and barium carbonates were effective catalysts because they were able to react with carbon at temperatures below the minimum temperature for the direct dissociation into metallic oxide and carbon dioxide (for example, $Na_2CO_3+C=Na_2O+2CO$); and because the products of the reaction accelerated the rate of carburisation by increasing the carbon monoxide concentration and by speeding-up the removal of carbon dioxide, forming fresh carbonate.

The role of energisers is, however, still a controversial matter and their function in pack carburising forms the subject of papers by Dr. Axel Hultgren.[2] He examined the effect of carburising a steel containing carbon 0·17, silicon 0·29, manganese 0·44 per cent, with low sulphur and phosphorus, under different conditions. Carburisation was carried out at 925 deg. Cent for twenty hours, the temperature of the boxes being raised from 500 deg. to 925 deg. Cent. in three hours. The degree of carburisation was measured by the depth at which hypereutectoid cementite disappeared ($d_c$), and the depth at which hypoeutectoid ferrite began to appear ($d_f$). For carburising in charcoal alone, $d_f$=1·0mm to 1·3mm and $d_c$=0·1mm to 0·3mm, the variation being due to different percentages of activating material, for example, potassium carbonate, naturally occurring in the charcoal. The corresponding values obtained with a good carburising medium were $d_f$=1·5mm to 1·7mm and $d_c$=0·5mm to 0·7mm.

### Factors Affecting the Activity of Energisers

Various ways of mixing crushed charcoal and energiser in the carburising box, with the specimens to be carburised, were studied and two methods were found to be equally effective: sodium or potassium carbonates applied as a layer on top of the charcoal, or barium carbonate applied as a thin coating to the steel surface, preferably with the aid of a binding agent, such as lacquer, and with the coated specimen packed in unmixed charcoal which had been thoroughly washed in dilute hydrochloric acid. The alkaline carbonates, on being heated to the carburising temperature, spread out, forming a uniform mixture with the charcoal. The barium carbonate has very little spreading power and remains where it is applied, exercising its energising function at the steel surface. Apparently the presence of an energiser is not required beyond a certain small distance from the surface. In carrying out the carburising process with barium carbonate-coated steel objects the presence of a small amount of potassium carbonate in the charcoal, or in the coating, may interfere with the carburising reaction in some unknown manner, leading to poor results. On the other hand, carburisers consisting of charcoal with mixed barium and potassium carbonates gave good results.

When a carburiser is used repeatedly it is necessary to mix a minimum quantity of fresh crushed charcoal, about 10 per cent of the total charge, with the spent carburiser each time it is re-used. A small amount of energiser should be added occasionally to compensate for the small evaporation and handling losses. When 33 per cent of potassium carbonate was originally added to the sample of charcoal, and about 10 per cent of fresh charcoal admixed each time the test was repeated, 10 per cent of potassium carbonate added after ten runs maintained good carburisation during the following ten runs with charcoal additions only. (If the energiser added is barium carbonate it must be mixed with the carburiser.) Provided that the boxes are well sealed, the shrinkage of the carburiser may be so small that simply replenishing with charcoal will not satisfy the above condition of minimum addition; if so, the steel objects must be more closely packed, thus increasing the ratio of steel surface to carburiser volume. The noticeable decline in carburising power of a powerful carburiser, used repeatedly without any additions, after two or three carburising cycles, is probably caused by a rapid loss of active surface area of the charcoal particles, and certainly not by loss of energiser.

### Mechanism of the Action

A 1 : 1 nitrogen-carbon dioxide mixture was passed at 925 deg. Cent and at a fixed rate of flow through a layer of charcoal or graphite, unmixed or with additions of KOH or BaO. It was found that the unmixed charcoal reacted slowly with carbon dioxide; but that a low concentration of carbon dioxide (approximately that of equilibrium with carbon) was obtained on adding KOH to the charcoal or graphite when the rate of flow was 0·5 litre per minute, and also on adding BaO to charcoal when the rate of flow was 0·006 litre per minute. On adding BaO to graphite the carbon-dioxide concentration obtained at 0·02 litre per minute was somewhat higher than the equilibrium value. Hence, Hultgren concludes (in much the same way as Ragatz) that carbonate energisers act as catalysts for the reaction $CO_2+C=2CO$. In this way a high concentration of carbon monoxide is maintained at the steel surface and carburisation is accelerated. In considering these results it must, however, be recognised that the flexibility of the conditions which may be imposed in pack carburising is small compared with that possible in gas carburising.

[1] M. Sutton and R. A. Ragatz: *Trans. Am. Soc. Metals*, 1941, Vol. 29, page 169; T. C. Fong and R. A. Ragatz: *ibid.*, 1944, Vol. 32, page 162.

[2] *Jernkontorets Annaler*, November 1951, Vol. 135, page 575; *Journal of the Iron and Steel Institute*, July 1951, page 245 and March 1952, page 261.

## Gallium

Of recent years much interest has been shown in liquid metals as heat-transfer media on account of their high thermal conductivity and consequent high heat-transfer coefficients, stability at high temperatures and high range of temperature in which they can work. Gallium with a melting point below 30 deg. Cent., and a boiling point of about 2000 deg. Cent., was marked down for intensive investigation for this purpose. Though a rare metal, it is widely distributed in zinc and aluminium ores and could be recovered in substantial amount if any useful demand existed. However, the corrosive effect of gallium, in contact with other metallic materials, is so great that the only metals capable of containing it at raised temperatures are tungsten and tantalum. Investigations have been carried out to find gallium alloys of lower melting point*. Thermal analysis of metals freezing at atmospheric temperature presents difficulty, but use was made of a Rosenhain temperature-gradient furnace adapted for low-temperature use by keeping the lower end at —72 deg. Cent., while the upper end was heated at various temperatures according to requirements. The 82 : 12 : 6 gallium-tin-zinc eutectic has been found to melt at 17 deg. Cent., and the 76 : 24 gallium-indium eutectic at 15·7 deg. Cent., or 60 deg. Fah. Though less corrosive than pure gallium, these alloys are far too corrosive in contact with other metals at raised temperature to permit of their use as heat-transfer agents, and this possible use of gallium can be written off as an unlikely development.

* J. P. Denny, J. H. Hamilton and J. R. Lewis: *Journal of Metals*, January, 1952, page 39; R. M. Evans and R. I. Jaffe: *Journal of Metals*, February 1952, page 153.

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### THE ECONOMIC SURVEY

WHEN annual Economic Surveys first began to be issued after the war, those who compiled them were confident in their planning. They laid down output targets for individual industries and, on paper, directed the flow of labour into particular manufactures. That mood of confidence has now passed. Hard experience has proved that economic changes cannot be planned in such detail in a relatively small country highly dependent for its national wellbeing upon a large import and export trade, with the world outside its borders and outside the control of its Government. In the Economic Survey for 1952, issued last Tuesday, no targets are laid down, nothing is confidently predicted. Only hopes are expressed. In fact, the economic situation as it stands is surveyed and no real attempt is made to forecast what changes may occur in the next twelve months except in very general terms. For example, in a reference to raw materials it is remarked that the United Kingdom "should . . . be able to get rather more copper this year than last" and that "provided . . . the means can be found to pay for them, other raw materials should be available in sufficient quantities to match the available supplies of steel or, where steel is not a limiting factor, to provide for the probable level of demand for finished goods." But "a large increase in American purchases would also directly affect the position, since the fall in American demand during 1951 was one reason for the improvement in raw material supplies." The note of cautious assessment sounding in those sentences is typical of the tone of the whole of this year's Survey.

This year the Economic Survey has been issued after, not before, the presentation of the Budget to Parliament. The change in timing necessarily takes away from the Survey that interest it used to have that it might give some clue as to the fiscal measures which would be contained in the Budget. Appearing after the Budget, however, the Survey can only repeat what the Chancellor has already preached and give, in very much greater detail, industry by industry, figures of production and consumption, particulars of the progress of rearmament, trends in employment, and so forth, the detailed figures and assessments of probabilities, in fact, upon which much of the Chancellor's Budget has been based. What is, however, brought out particularly well in the Survey is the extent to which this country is becoming dependent for increasing exports on the engineering and allied industries. In 1951, a year in which the rate of expansion of output was checked by shortages of steel and other materials, and in which the amount that could be exported was also limited by the needs of rearmament, metals and engineering products provided nearly half the total exports of this country at £1201 million out of a total of £2580 million. In the present year the dependence of the country upon the engineering and allied industries to support its balance of payments is likely to become even larger. For "the outlook for consumer goods exports in 1952 is not promising," and "in present conditions of world demand the expansion of the total volume of exports must depend almost entirely on increasing engineering exports." One of the difficulties noted in the Survey as being encountered in expanding engineering output and maintaining the pace of rearmament is the shortage of skilled labour—a shortage of which many engineering factories have been only too well aware for several years past! A shortage of scientists and highly qualified technicians is noted "in the electronics industry." That shortage certainly extends into other fields as well.

Had it been possible, the wise choice of the Government in attempting to right Britain's adverse balance of trade would have been to restrict personal consumption at home; in fact, temporarily, to reduce living standards. Unfortunately, as events and the Survey between them make clear, that policy was not practicable. For, save by rationing and by extending strict controls and restrictions, it is difficult enough merely to hold down personal consumption to a steady level, let alone reduce it. As soon as the attempt is made to restrict it by the other means of letting prices increase, demands, such as those the Confederation of Shipbuilding and Engineering Unions and the National Union of Railwaymen are likely soon to press, are made for increased wages sufficient to balance, or even to over-balance, the consequent increased cost of living. In fact, however, limitation of consumption at home, though it might have helped to reduce import demand, could have done little, this year, to help exports when the world demand for British consumer goods is no longer advancing. A sane assessment of world demand made it obvious that only engineering exports could confidently be expected to increase this year, and since the engineering industry, despite the rapidity of its expansion, cannot be expected simultaneously to carry the burdens of re-equipping this country's industries, re-arming its Forces, and increasing its exports, no choice was left but to divert productive capacity, which might have been used for capital products, to rearmament and to assign to export markets many engineering products of which industries in this country stand sadly in need. That diversion of capital products is planned to reach a total of some £250 millions, through reduction of capital expenditure by that amount in this country. The policy is not one which has much to recommend it save under the conditions of the present emergency. For by restricting capital expenditure at home future enhanced living standards are being mortgaged to maintain the lesser living standards of to-day. It is therefore very much to be hoped that as soon as the emergency is over the policy will be reversed.

### TECHNICAL EDUCATION AND INDUSTRY

SPEAKING in the House of Lords during a debate on proposals for promoting full employment, Lord Samuel is reported to have expressed the view that the most important sentence in the White Paper was that which declared technical efficiency to be "the dominating factor in the growth of real national income." He therefore pressed the need for giving special encouragement to research and education. That ceaseless research is of vital importance to industry has long been axiomatic, but there are no very clear rulings as to how research, if it is to be of maximum value to industry, can best be conducted. That industry should assist itself by conducting its own research is a principle already established, but this leaves out of consideration the education of potential researchers. Here is where the technical college, the research laboratory and industry, operating as a team, can play an essential part. That noted research worker, Charles F. Kettering (former Vice-President and Director of Research, General Motors Corporation, Detroit), has remarked that he "would like to see the university and industry work closer together because I think they should understand each other's problem. I think if we could do that it would be much less necessary to teach trade subjects in school. We could spend more time on the fundamental broad principles of physics, chemistry and mechanics."

A reflection sobering to technical educationists generally is that a recent survey should have shown that if a person had an engineering or scientific education, "the probability of his making an invention was

only about half as great as if he did not have that specialised training." We need to make the teaching in technical schools an education rather of the imagination than of the memory. Imagination is a quality innate in our race, and its stimulation should be a vital function not only of technical but of all education. Without imagination there can be no criticism and without criticism no progress. Imagination is not, of course, the same thing as intuition. By imagination we form images of objects not present. Intuition, on the other hand, is immediate apprehension without reasoning. No finer example of its power can be quoted than that displayed by the late Sir Charles Parsons, of whom it has been written that "His intuition served him as an infallible guide in design and elementary arithmetic suffices for such calculations as he ever made." It will be admitted by all teachers that one of the most difficult problems in the work of education is to diagnose the bent of those who present themselves for instruction. It is a problem which has engaged teachers since the time of Isocrates and it will so continue. The main work of the teacher of science is—or should be—to make the student a self-propelling thinker rather than the conventional (and sometimes arrogant) product of highly specialised knowledge. Kettering tells of a man who, having witnessed a test on one of their engines, came to see him. "That is a very efficient engine," he said. "I would like to talk to your thermodynamics expert about it." "I am sorry," replied Kettering, "we don't have anyone here who even understands the word 'thermodynamics,' much less be an expert on it. But if you want to know how we developed this engine I'll be glad to show you." No one knew better than Kettering that laboratory equipment, important as it is, cannot by itself produce a research student. Some of the most momentous progress ever accomplished by scientists has owed little or nothing to laboratory equipment. Pasteur worked in an attic under the roof of the Ecole Normale, from which he was frequently driven by the insufferable heat. Nevertheless, it was in such surroundings that he organised his experiments on the problem of fermentation. What sort of laboratory was available for his countryman, Carnot, is not related. We do know, however, that both men accomplished their epoch-making work by the exercise of imaginative powers of great strength and originality. "A moment's insight is sometimes worth a life's experience."

The argument here is not that the perceptive genius of such as Pasteur and Carnot can flourish best in an ill-ventilated and ill-equipped attic. No researcher in the history of science has better declared, than did Pasteur, the need for adequate laboratories. In his memorable appeal issued during 1868, he told Napoleon III and the French Nation that "The boldest conception, the most legitimate speculations, can only be embodied by observation and experiment.... Physicists and chemists without laboratories are like soldiers without arms on the battlefield." He stressed the laboratory rather than the library and held that laboratories should be centres of interest of the towns in which they were situated and that every district should be in association with its university. The question of technical education is a matter well recognised as of crucial importance for the future of Great Britain, and we can be thankful that it has become the declared and immediate concern of successive Governments. Let it not be forgotten, however, that it is the intellectual aspect of technical education which transcends all others and that unless the critical faculties can be stimulated, no laboratory will suffice as a true cradle of technical progress. We need to be reminded, perpetually, of the inspired words to students, which, among the last public utterances of Louis Pasteur, should be set up like a banner in every engineering laboratory: "Worship the spirit of criticism. Left to itself it is neither a generator of ideas nor a stimulant to great things. But without it nothing can avail. With it will always remain the last word."

## Literature

*Aerodynamics of Supersonic Flight.* By ALAN POPE. London: Sir Isaac Pitman and Sons, Ltd. Parker Street, Kingsway W.C.2. Price 25s.

IT is not so very long ago that supersonic flight was merely of academic interest. The rapid developments of turbo-jet and rocket propulsion units have now brought supersonic aircraft and missiles into the field of practical engineering. A book of this nature is thus particularly welcome as a short and readable account of the problems associated with this new aspect of locomotion. The book is, indeed, intended as a short-course introduction to supersonics. The treatment is non-thermodynamic, but the reader is assumed to have a knowledge of calculus and elementary aerodynamics.

The work opens with a useful restatement of fundamentals and such definitions as those of Mach number, the gas laws, adiabatic and isentropic processes and Bernoulli's equation. These introductions lead naturally and easily to flow in a duct, and the reader is shown how duct contours influence this flow, thus introducing the supersonic expansion nozzle. Effects of exhaust pressure and the formation of shock waves are discussed, and an explanation given of the limiting speed for exhausting into a vacuum. Stagnation temperature is discussed. An analysis of two-dimensional flow explains the Mach cones and supersonic flow around corners. First discussion is on the corner inclined away from the flow which produces a supersonic expansion, the Prandtl-Meyer corner. This theory is then used to explain the familiar diamond shock pattern of a supersonic nozzle exhaust. The concave kind of corner is shown to result in an oblique shock. This is discussed in detail, leading ultimately to the theory of the supersonic airfoil. Useful approximate theories for evaluating airfoil characteristics are then presented, the Ackeret linear theory and the Busemann series, and their limitations are discussed. It is pointed out that despite these limitations these quick approximations are sometimes preferable to the use of charts compiled from the exact theory. There is an interesting chapter about supersonic wind tunnels and their associated problems. The difficulties of supersonic tests are mentioned and the shadowgraph, schlieren apparatus and interferometer are described and compared.

The final section of the book is concerned with three-dimensional flow, induced drag, various supersonic wings, sweep-back, rectangular, trapezoidal and delta wings, and the Busemann biplane. A brief mention is made of supersonic power plants and an example supersonic airplane is designed. The book is well illustrated, though the frontispiece appears to have been changed without alteration of the text. Good examples of each stage of the theory are completely worked out in each chapter, and there are many problems for the reader to tackle. Not the least important in this respect is the useful addition of answers to these problems.

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*Chill-Cast Tin Bronzes.* By D. HANSON and W. T. PELL-WALPOLE. London: Edward Arnold and Co. 1951. Price 75s.

THERE can be little information relating to the tin bronzes that is not contained in this well-produced volume. Incidentally, it constitutes a worthy record of work on this subject, sponsored in the first instance, by the Tin Research Council, and carried out at Birmingham University and at the Tin Research Institute. The primary object of the book is to provide a complete survey of the metallurgy of bronze in the form of ingots and castings made in metal moulds. Chapters on melting methods, recommended melting procedure and chill-casting practice are of direct interest to the practical foundryman, advice under these headings being based very largely on researches carried out by the authors and their colleagues in collaboration with the Tin Research Institute. These researches are described in detail. The chapters on properties and uses of the bronzes, the effect of additional constituents (phosphorus, zinc, &c.), the heat-treatment of cast bronze and the fabrication properties and uses of the wrought bronzes are packed with data in the form of tables and diagrams, including the results of some previously unpublished work of the authors. The book will appeal, however, to a far larger circle of readers than those interested in the chill-casting of bronzes. The introductory chapter on the historical development of bronze is of wide general and cultural interest. It traces the development of the metallurgy of bronze from the earliest times down to the end of the 19th century. The history of bronze statuary, of bell founding and of the use of bronze for ordnance is dealt with in some detail. Much of the discussion on casting methods should be of interest to all dealing with the casting of other non-ferrous metals, and so should the excellent review of segregation and the theories of inverse segregation. The engineer, also, is plentifully supplied with information about the properties and uses of a wide range of bronze products. It seems a pity that this excellent material is not available, in a more compact form and at a lower price, to those who are not directly concerned with the production of chill-cast tin bronzes, the discussion of which occupies the bulk of the text. Meanwhile, the book may be expected to take its place as the standard work of reference on all aspects of the subject.

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## BOOKS RECEIVED

*Principles of Alternating Currents.* By W. Sluckin. London: Cleaver Hume Press, Ltd., 42a, South Audley Street, W.1. Price 10s. 6d.

*Refrigeration Principles and Practice.* By Ezer Griffiths. London: George Newnes, Ltd., Tower House, Southampton Street, W.C.2. Price 42s.

*Building and Civil Engineering Plant.* By Spence Geddes. London: Crosby Lockwood and Son, Ltd., 39, Thurloe Street, S.W.7. Price 30s.

# Obituary

## SIR CHARLES INGLIS, F.R.S.

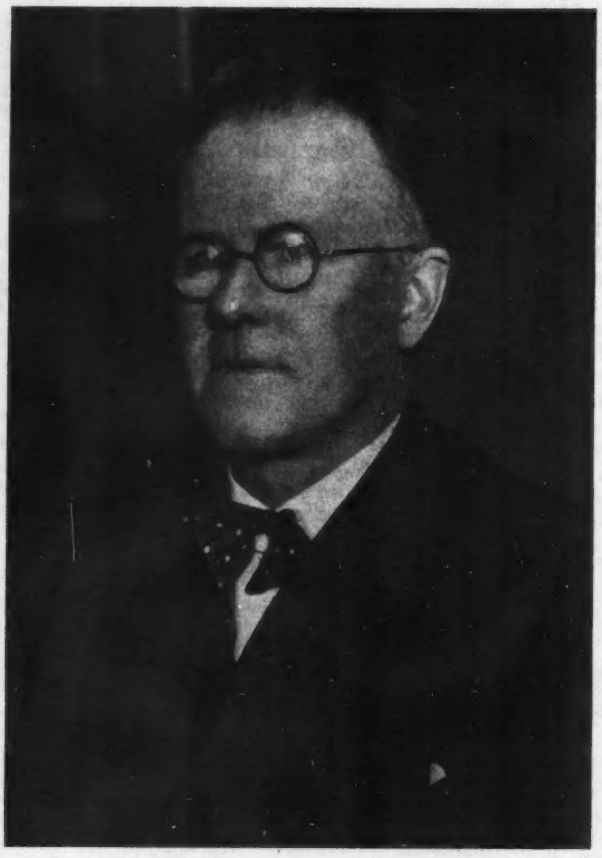
It is with deep regret that we record the death of Sir Charles Inglis, of 10, Latham Road, Cambridge, which occurred suddenly at Southwold on Saturday last, April 19th. Sir Charles, who was seventy-six, held a distinguished place in engineering education. He was, for twenty-five years, Professor of Mechanical Sciences at Cambridge University, where he began his teaching career under the late Sir. J. Alfred Ewing in 1901.

Charles Edward Inglis, who was the son of a Doctor of Medicine, was born at Worcester on July 31, 1875. He was educated at Cheltenham College and at King's College, Cambridge, where he gained a first-class mechanical science tripos in 1898. In the same year he began a pupilage with the late Sir John Wolfe Barry, spending one year in the drawing-office and two years on railway and dock construction work. During his pupilage Sir Charles took up the study of mechanical vibration, a subject to which he devoted much attention throughout his career. He was awarded a Fellowship of King's College, Cambridge, for a treatise on "Balancing Engines," and in 1901 joined the teaching staff of the University Engineering Department, of which Sir Alfred Ewing was then the head. That was the beginning of an active teaching career that extended over more than forty years. Shortly after his appointment, Sir Charles became university demonstrator and lecturer in mechanical engineering.

Upon the outbreak of the first world war in 1914, Sir Charles took a commission in the Royal Engineers and was for some time engaged as a lecturer at the School of Military Engineering, Chatham. But as the war proceeded he was appointed to take charge of a department of the War Office concerned with the design and supply of military bridges necessary for operations overseas. He was responsible for the invention of the Inglis portable tubular bridge, which was accepted as a standard of sapper equipment, and his work at the War Office included also the design of other structures, such as forts and observation towers. In recognition of his war services, Sir Charles was awarded the O.B.E.

Sir Charles returned to Cambridge University in 1919 and in April of that year was appointed Professor of Engineering—or Professor of Mechanical Sciences, as he was later known—a position in which he served until his retirement twenty-five years later. His occupancy of the Chair of Engineering at Cambridge undoubtedly represented the most important part of Sir Charles's work. His first main task was the reorganisation of the engineering department consequent upon the building of new laboratories and lecture rooms. Instruction in engineering had begun at Cambridge University round about 1890, and although the question of new premises to accommodate the increasing number of students had been seriously considered in 1914, the war put a stop to development. In 1920, however—a year after Sir Charles's appointment as Professor—work was started on the construction of the buildings now occupied. The new laboratories, which were built on a site extending over 4 acres, were described in detail in THE ENGINEER of October 24, 1924. Inspired by the high standard set by Sir Alfred Ewing, Professor Inglis saw to it that engineering education at Cambridge progressed along sound lines. Some of his ideas and ideals were conveyed in an address which he delivered to the Institution of Mechanical Engineers on the occasion of its summer meeting in Cambridge in July, 1931. In the course of that address Sir Charles urged that in a university course of engineering, instruction should primarily concentrate on teaching those essentials which, if not acquired at that stage, never would be acquired! Technicalities which would automatically be picked up in a student's subsequent career were useful, he claimed, as stimulating interest, but, apart from that, they were of secondary importance. Education, Sir Charles suggested, did not consist in the memorisation of a number of facts and formulæ, useful as they might be when leavened with intelligence. Education at its best, he said, should aim at something much deeper and more lasting, and the good of education was the power of reasoning, and the habit of mind which remained, when all efforts of memorisation had faded into oblivion.

Although his work at Cambridge University always took first place, Sir Charles found time to render valuable service in many other spheres. His wide experience and expert knowledge were called upon by various Government and other public committees of inquiry. He served, for instance, on the committee set up by the Secretary of State for Air to investigate the crash of the airship "R101" in 1930, and, much more recently, he presided over the Railway (London Plan) Committee, which presented a report to the Minister of Transport in 1946, setting out a scheme of railway development best suited to the future needs of the London area. Valuable contributions to the work of many learned societies were made by Sir Charles. He became an associate member of the Institution of Civil Engineers in 1901 and a full member in 1922. In 1924 he was awarded a Telford Gold Medal by that Institution for a paper on "The Theory of Transverse Oscillations in Girders and its Relation to Liveload and Impact Allowances," and in 1941—in one of the most difficult periods of the second world war—Sir Charles was elected president of the "Civils." His presidential address, delivered in November, 1941, dealt with "The Education of Engineers." Another outstanding contribution which Sir Charles made to the *Proceedings* of the Institution of Civil Engineers was the Trevithick Memorial Lecture, delivered at the bicentenary commemoration of Trevithick's death in April, 1933. In 1944—just after his retirement from the Chair of Mechanical Sciences—Sir Charles gave the fiftieth James Forrest Lecture to the Institution of Civil Engineers, which dealt with the cause and prevention of mechanical vibrations. In this lecture Sir Charles presented an excellent survey—based on his long experience—of the principles involved. The examples discussed included the vibration of turbine blades, the seismograph, torsional oscillations in crankshafts, oscillations induced in railway vehicles by the sleepers and rail joints, vibrations in railway bridges, and oscillations of a non-isochronous spring.



SIR CHARLES INGLIS

Sir Charles was elected to membership of the Institution of Mechanical Engineers in 1921, and in 1943 was its Thomas Hawksley lecturer, taking as his subject "Gyroscopic Principles and Applications." Honorary membership of the Institution was conferred upon him in that year, and when, in 1947, the Institution celebrated its centenary, it invited Sir Charles to contribute to its programme of special lectures. He spoke then on "Solid Body Mechanics in Relation to Mechanical Engineering." Sir Charles was a member of council of the Institution of Naval Architects, and of the Institution of Structural Engineers, and a past-president of the British Waterworks Association. He became a Fellow of the Royal Society in 1930.

From 1943 to 1946 Sir Charles was Vice-Provost of King's College, Cambridge, and after his retirement from the Engineering Department at the beginning of 1944 continued with consulting work. His great services to the cause of engineering education were recognised by the Knighthood which he received in the Birthday Honours of 1945.

# Cavitation Mechanics in the Design of Hydraulic Equipment

JAMES CLAYTON LECTURE—No. I

By PROFESSOR ROBERT T. KNAPP, Ph.D.*

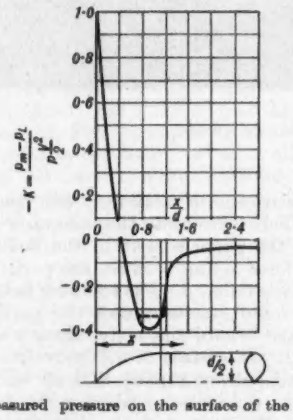
*The objective of this James Clayton Lecture, presented to the Institution of Mechanical Engineers on April 18th and here abstracted, is to outline the various characteristics of the cavitation phenomenon and to point out in general how this knowledge may be used to alleviate and, in some cases, to eliminate the losses due to damage of materials and decrease in performance of hydraulic equipment. It is shown that difficulty with cavitation is encountered over the entire field of hydrodynamics, but that, although the manifestations may appear to differ widely, they can usually be understood on the basis of present concepts of the mechanics of cavitation. It is found that such understanding usually brings with it suggestions of methods for lessening or eliminating the difficulty. The first part of the lecture, mainly descriptive of the California Institute of Technology high-speed water tunnel, is omitted.*

## Experimental Results and Conclusions

*Definition of Cavitation Parameter.*—In the discussion of all types of cavitation problem, experimental results, and performance of equipment, some system of describing quantitatively the dynamic conditions under which the cavitation is taking place immediately becomes necessary. Fortunately, such a system has won universal acceptance. It involves the use of a dimensionless quantity called the cavitation parameter, and is given by

$$K=\frac{p_L-p_B}{\rho\frac{V^2}{2}}=\frac{h_L-h_B}{\frac{V^2}{2g}}$$

where (in consistent units) $p_L$ and $h_L$ are the pressure and pressure head in the undisturbed liquid, $p_B$ and $h_B$ are the vapour pressure and pressure head corresponding to the liquid temperature, $V$ is the relative velocity between the body and the liquid, normally measured where the liquid is undisturbed, $\rho$ is the liquid density, and $g$ is the acceleration due to gravity.




$p_m$ measured pressure on the surface of the body.

FIG. 1—*Test Body and Cavitation Parameters*

*Physical Significance and Uses of Cavitation Parameter.*—The physical significance of this parameter is clear. The numerator is the net pressure or head which acts to collapse the cavity. The denominator is the velocity pressure or head of the flow. Now the variations in pressure which take place on the surface of the body or on any type of guide passage are due basically to changes in the velocity of the flow. Thus the velocity head may be considered as a measure of the pressure reductions that may occur to cause a cavity to form or expand. From this point of view the cavitation parameter is simply the ratio of the pressure available for collapsing the cavity to the pressure available for inducing the formation and growth of the cavity. It transpires that this parameter $K$ is a very useful measure for many different aspects of the cavitation phenomenon. For example, if the first traces of cavitation appear when $K=K_i$ (incipient cavitation), $K_i$ can be interpreted as the maximum reduction in pressure on the guiding surface, measured in terms of the velocity head. Thus, if $K_i=1$, the lowest pressure at any point on the surface is one velocity head below that of the undisturbed flow. It follows directly that $K$ can be used to designate the relative cavitation resistance of a given nose shape or an entire piece of hydraulic equipment. This is accomplished by assigning to the object its measured value of $K_i$. The lower this value, the higher is the object's resistance to cavitation.

Many similar uses are found for this parameter, some of which will be discussed later. Therefore, it is always necessary to specify the use which is being made of $K$ in each particular case, as for example, $K$ for incipient cavitation, $K$ for a fully developed cavity, $K$ that characterises the flow conditions, &c. In this connection one very convenient use is for the comparison of the condition of the flow with the cavitation resistance of the object. For example, consider a centrifugal pump installation. Assume that for the best available pump for this installation $K_i=0·4$, measured at the inlet. This means that the user must install the pump at an elevation low enough for the $K$ value of the flow entering the pump never to be less than 0·4. If he is able to do this, then he can be sure of cavitation-free operation. If not, then cavitation can be expected to occur at all times when the $K$ value of the flow drops below 0·4. It will be noted that the value of $K$ varies if either the pressure or the velocity is changed. This is particularly important when $K$ is used to define the character of the flow. Thus the $K$ value of the tunnel working-section may be varied over wide limits by simply varying the pressure level while the velocity remains constant.

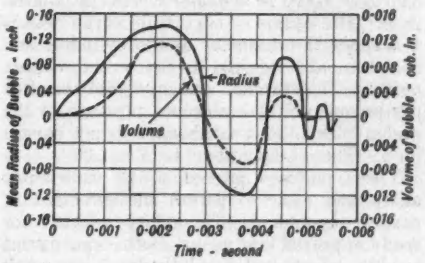



FIG. 2—*Time-Radius Curves of Bubble*

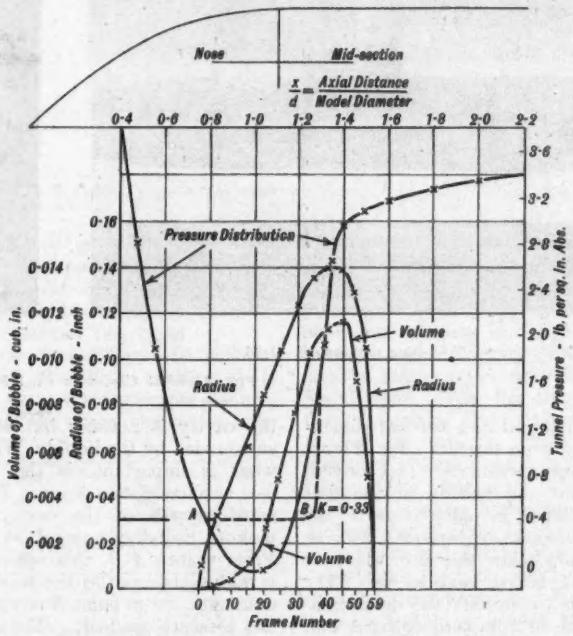



FIG. 3—*Relation of Bubble Growth and Collapse to Pressure*

*Inception and Life History of a Cavity.*—The high-speed motion-picture technique makes it possible to trace in considerable detail the life history of a cavity, from its inception to its final disappearance by means of a strip of pictures, taken at the rate of 20,000 frames per second. The portion of the test body seen in such a strip is a

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very narrow band along the top, and the the cavities are practically in silhouette; each horizontal line represents an individual photograph. A line drawing of the test body is shown in Fig. 1, which in practice is drawn to the same scale as that of the photograph. The relative location of the cavity on the body is then obtained by projecting any individual picture vertically upward on to the diagram. The test body is a cylinder with a pointed nose. The radius of curvature of the nose is 1·5 times the diameter of the cylinder, and is commonly referred to as a 1·5 calibre ogive. The tunnel was operated at 40ft per second and the absolute pressure in the undisturbed flow was about 4 lb per square inch. This is equivalent to $K=0·33$.

These pictures proved to be sufficiently sharp and clear to permit measurement of cavity diameters. The cavity selected for study appeared first as a smooth, transparent bubble, which had a relatively slow growth and a much more rapid collapse. After complete collapse it reappeared, this time with a rough, irregular wall. Nevertheless, the growth and collapse cycle was repeated. A third cycle followed, and then a fourth, fifth, and sixth, each successive one being smaller. Measurements were made of this cavity on each frame. The average cavity radius was assumed to be one-half of the mean of the horizontal and vertical dimensions as measured from the film. Fig. 2 hows a plot of these measurements. The convention used is that the history of the first growth and collapse is plotted above the zero line, the second appearance, that is, the first rebound, below the line, the next above, the next below, and so on. The reason for this is to simplify the determination of the time of complete collapse and to avoid confusion between the last stages of collapse and the first stages of rebound. The dotted line shows the volume history on the assumption that the cavity is a sphere.

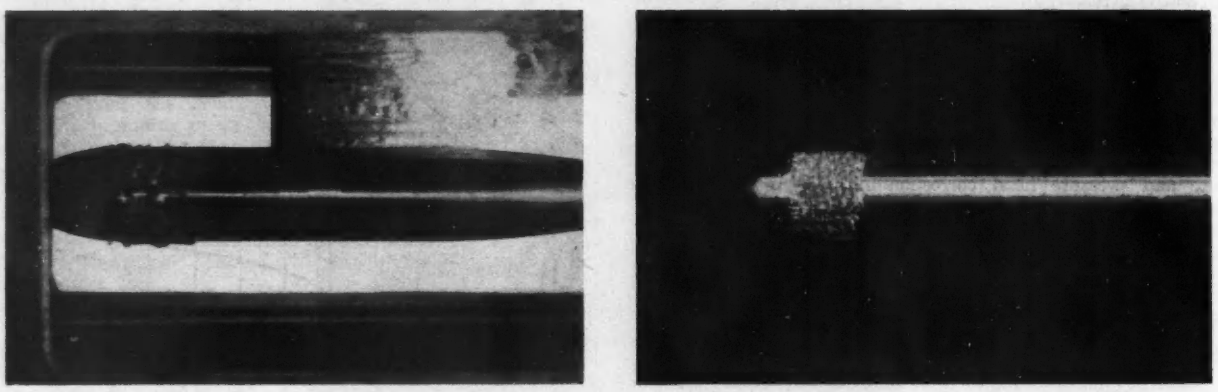
*Details of Cavity History.*—It is possible to obtain considerable insight into the mechanics of this process by examining in detail the life history of this one cavity, which is typical for at least one important type of cavitation. Fig. 3 will assist in this study. At the top will be seen the half-profile of the test body. The graph below it, drawn to the same longitudinal scale, shows the pressure distribution on the surface of the body and the behaviour of the cavity from its inception to its first collapse. It will be noted that only the negative portion of the pressure distribution curve is shown. The ordinate for this curve is absolute pressure. The vapour pressure of the water, at the temperature of the experiment, is shown by the horizontal dashed line. The pressure distribution is that measured for non-cavitating conditions, that is, for a high value of $K$. The dotted line having the horizontal section $A$-$B$ shows the changed pressure distribution for $K=0·33$. The curves showing the radius and volume of the cavity are the same as those seen in Fig. 2 with the exception that the abscissa is distance, measured along the test body, instead of time.

Point $A$ shows the position on the nose of the body at which the pressure has been reduced to the vapour pressure of the water. This is also very nearly the position at which the cavity is first detectable as a tiny bubble. The cavity moves downstream on the body and as seen from Fig. 3, it is moving into a region in which the pressure tends to decrease below the vapour pressure. Therefore it is not surprising to observe that the cavity grows at a rapid rate. This high rate of growth continues nearly to point $B$, which corresponds to the position on the body at which the pressure climbs up back to vapour pressure.

*Cavity Hydrodynamics.*—It must be remembered that references to the behaviour of the cavity and the motion of the cavity wall are really only figures of speech. So far as the dynamics of the system are concerned, the cavity is nothing but an empty space surrounded by the liquid. What is seen, and what is important, is the motion of the free surface of the liquid. Thus during the rapid growth of the cavity the liquid is moving radially outward at a high speed. From points $A$-$B$, this outward radial flow is taking place in the direction of the pressure gradient. From point $B$ onward, it is against the pressure gradient. Thus, as the curves for both radius and volume show, this motion is decelerated, and finally ceases at the point of maximum radius. The cavity radius then begins to shrink at a rate that indicates a high radially inward acceleration. This is confirmed by reference to the pressure diagram. If it is assumed that the pressure inside the cavity is the vapour pressure, there is a pressure difference of approximately 2·5 lb per square inch acting to produce this acceleration. It will be recognised that this pressure difference is the numerator of the cavitation parameter. Viewed with respect to the pressure distribution diagram, the behaviour of the cavity is very rational; indeed, it could have been predicted from Newton's laws of motion. On the other hand, such a prediction requires a knowledge of the pressure distribution diagram.

The question might well be asked as to the physical explanation of the pressure variation on the body. It is not difficult at this point to become confused as to whether the motion of the liquid produces the pressure variations on the body or whether the pressure variations on the body cause the motion of the liquid. Such confusion is largely a confusion of terms. Any fluid particle may be considered as a free mass with an associated force system. Consider such a particle of liquid in the flow which impinges on the nose of the body near the point and follows along the surface. Since the particle cannot penetrate the surface of the body, it has to move laterally to get around it. To move laterally, however, the particle must shove other particles out of the way. The effect of these collisions, combined with force applied by the body to prevent the liquid from passing through its surface, is manifested in the pressure field that develops. The lateral outward acceleration of the original particle continues until it and all of the adjacent particles are moving parallel to the body surface. It will be found that when this state is reached, the pressure on the surface has decreased until it is equal to the static pressure in the undisturbed flow, that is, the particles have acquired a lateral component of motion high enough to keep them out of the way of the body. Downstream from this point the surface of the body curves away from this tangential path. This takes away the constraint on the side of the particle next to the body, that is, the force acting between the particle and the body is reduced. The resulting unbalance of the force system causes the particle to accelerate toward the body, along a curved path. If the surface of the body falls away from this path so rapidly that all constraint on the particle is removed, then the pressure between the body and the particle is zero. The minimum radius of curvature of the particle in this case will be determined by the free stream pressure. If the body falls away from the path of the particle even more rapidly than this, there are two possibilities: either a tension force must be set up between the surface of the body and the particle, to constrain the particle to follow the curvature of the body, or else the particle will leave the body surface. In the latter case a cavity must form.

Thus it is seen that cavitation will take place only in regions in which the guiding surface is curving away from the local direction of flow. Whether or not cavitation actually takes place will be determined by whether the radius of curvature of the surface at the point under consideration is greater or less than the minimum radius of curvature of the filament of liquid next



(*a*) Travelling cavities, $K=0·26$. (*b*) Fixed cavity, $K=0·27$.

FIG. 4—*Light Cavitation on 1·5in Calibre Ogive*

to the surface, if the pressure on the concave side of this filament is assumed to be vapour pressure. If the surface radius of curvature is greater than the minimum filament radius, no cavitation will occur. If it is less, then cavitation takes place, that is, the liquid flow breaks away and produces voids †. The salient features of this cavitation process are :—

(1) The cavity starts to form at the point on the guiding surface where the pressure is reduced to vapour pressure.

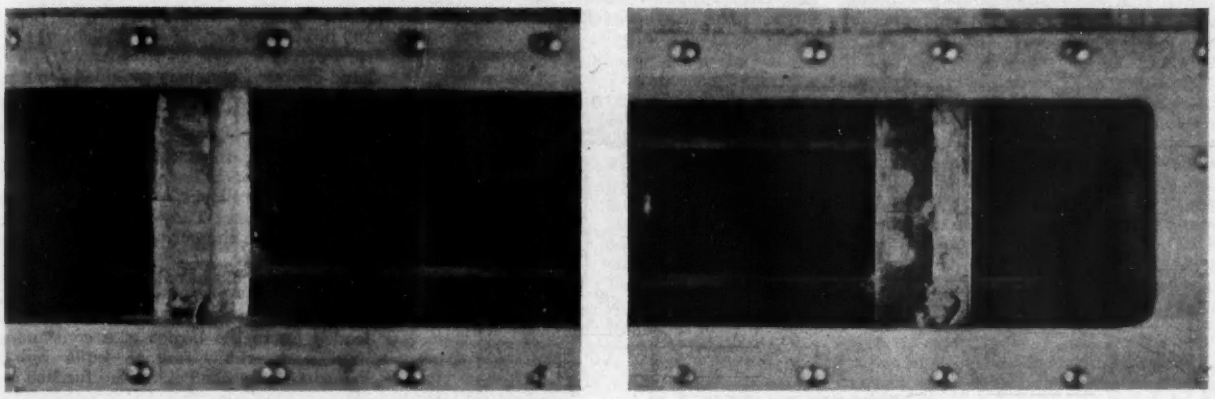
(2) Cavity growth continues as long as the surface pressure is at or below vapour pressure.

(3) As the pressure on the surface increases until it is again above vapour pressure, the rate of cavity growth decelerates; the cavity quickly reaches the maximum size, and immediately starts to collapse.

(4) The collapse rate is much higher than that of formation.

zone in which the travelling cavities, seen in Fig. 4*a*, go through several cycles of rebound and collapse. The corresponding history of the fixed type of cavity, typified by Fig. 4*b*, seems to be that large sections of it are entrained by the flowing stream of liquid and are swept downstream, where they disappear. Fig. 5 shows entrainment on the upper and lower surfaces of a hydrofoil. It should be remembered that this entrainment takes place at the downstream end of the low-pressure zone, and collapse and disappearance occurs in a region where the pressure is above vapour pressure. In this type of cavitation the cavity elements are extremely irregular in shape and by no stretch of imagination could be considered as spheres. Thus the mechanics of their collapse is very complicated; presumably, much of the energy associated with it is dissipated in the process, as it is difficult to find clear

equated the kinetic energy of the resulting motion of the fluid to the work done at infinity by the constant pressure acting through a change of volume equal to the change of the cavity volume. Fig. 7 gives a comparison of the observed collapse with that predicted on the basis of these simple assumptions. It will be seen that the agreement is surprisingly good, so good that it leaves little reason to doubt that the basic mechanics are as Lord Rayleigh visualised. He also calculated the pressure that would result if the cavity collapsed concentrically on to a small, infinitely rigid sphere‡. He abandoned the assumption of the incompressible fluid at the instant that the cavity wall touched the surface of the sphere, and proceeded to determine the pressure on the surface of the sphere on the basis that the kinetic energy present in the liquid just before the instant of contact was converted to potential energy of



(*a*) Upper surface, $K = 1 \cdot 36$ (*b*) Lower surface, $K = 0 \cdot 82$

FIG. 5—*Entrainment from Fixed Cavity on Surfaces of Hydrofoil*

*Cavitation Types.*—Fig. 4 shows two single-flash pictures both taken of the same test body but at slightly lower values of $K$ than that of the motion-picture strip associated with Fig. 1. It was observed that the cavitation seen in Fig. 4*a* appeared the same as that shown in the strip; whereas that seen in Fig. 4*b* seems quite different. This illustrates clearly that there are different types of cavitation, and furthermore, that at least these two types can exist under nearly the same conditions. The differences between these two types will be discussed later, but first an examination will be made of the similarities, which are more significant than is obvious at first glance. They are :—

(1) The cavities first appear at the same point on the guiding surface, that is, at about the point where the vapour pressure is reached.

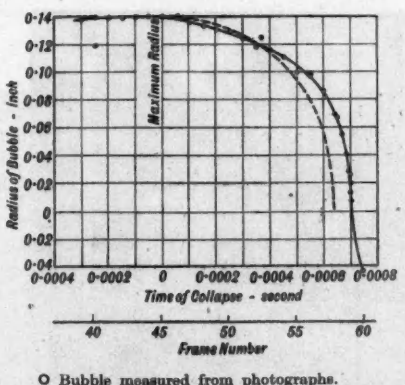
(2) The cavitation zones cover the same part of the body.

(3) The thickness of the cavitation zones seem to be about the same.

Therefore, in these important features the two types of cavitation are equivalent.

One of the most obvious points of difference is found in the zone immediately downstream from the main cavity region, that is, the evidence of repeated rebounds and recollapses. It should be emphasised that, even with this apparent difference in appearance, these parts of the cavitation process are basically similar for the two types.

*Analysis of Cavity Collapse.*—In collapse of the spherical travelling cavities it is possible, on the basis of some simple assumptions, to calculate the size of the cavity from




○ Bubble measured from photographs.
— — — Rayleigh theoretical curve from equal maximum diameter and pressure difference.
● Rayleigh theoretical points for maximum diameter and time.

FIG. 7—*Comparison of Bubble Size with Rayleigh Prediction*

the time it has reached its maximum diameter until it has completely collapsed. This was first done by Lord Rayleigh (1917), who considered the collapse of an empty spherical cavity in an incompressible fluid, having a constant pressure at infinity. He

compression as the liquid came to rest. This is the same physical picture that underlies all calculations of water-hammer pressure. If the slope of the theoretical or experimental curve in Fig. 7 is used to compute the radial velocity of the water as the bubble radius approaches zero, it will be found that, even for this small bubble, these velocities are measured in hundreds of feet per second. Thus the maximum pressures obtained must be very high, certainly of the same order as the elastic limits of metals used in hydraulic machinery.

*Cavitation Noise.*—The prediction of these high pressures during the collapse phase sheds some light on another aspect of the cavitation phenomenon. Everyone familiar with cavitation is aware that the process is noisy. The collapse zone must be a very effective sound source. The pressures are high and the pressure fronts are steep. Undoubtedly some of the energy involved will be dissipated in the form of pressure pulses. This probably accounts, in part, for the damping observed between the successive rebounds of the cavity whose history is plotted in Fig. 2. It might be mentioned in passing that many investigators have found it discouraging to work in a field that Lord Rayleigh has reaped. The gleaning of what little is left of the harvest usually requires a large amount of labour. Certainly the best of the crop is gone. Thus in the analysis of the collapse of these cavities,

† At this point the question might well be asked why there is necessarily a void. Why should not a liquid eddy form at this place between the body and the main flow? One answer is that under the conditions described, the outer surface of the eddy will be at vapour pressure and the core will be at even lower pressure. Thus vapour will form in the core of the eddy and force the outer layers into the surrounding flow where they will be entrained and swept downstream. It seems logical to expect that this process will continue until the whole volume is vapour-filled. From this point of view any separation zone is a potential cavitation zone and will become one if the pressure is sufficiently reduced.

‡ The reason for assuming the existence of the sphere is to obtain a finite collapse velocity, since, for a perfect incompressible fluid the collapse velocity approaches infinity as the radius of curvature approaches zero. This assumption would not be necessary if the calculations could be made for a real compressible fluid.

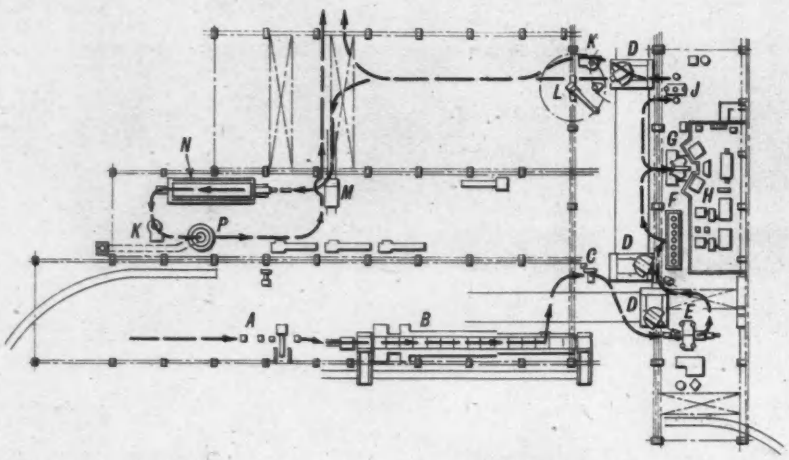
it is obvious that the liquid is not incompressible nor infinite in extent and the pressure is not constant at the boundary. Furthermore, the cavity is not empty but is vapour-filled and possibly contains some permanent gas. The amount of higher mathematics and labour required to make even approximate corrections for these additional factors is very discouraging, especially when a second glance at Fig. 7 shows that Lord Rayleigh's predictions are correct to within 10 per cent.

*(To be continued)*

# A Wheel Mill at Sheffield

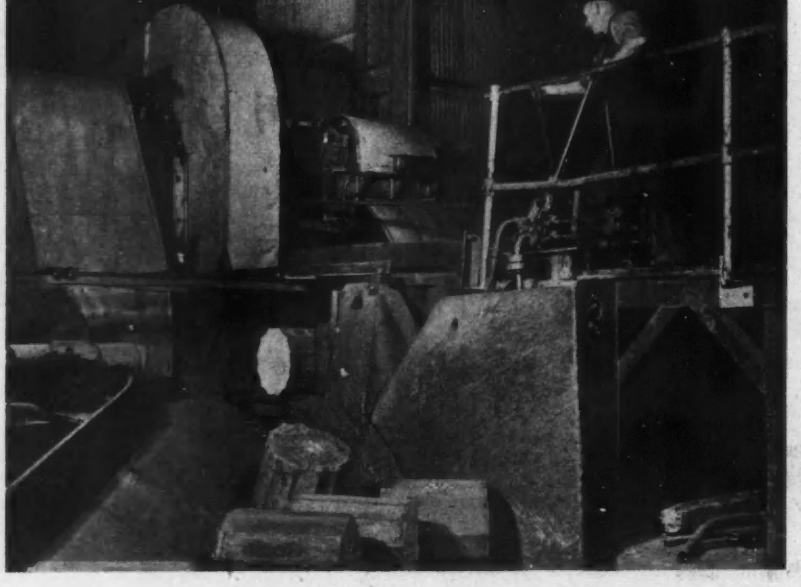
*The Steel, Peech and Tozer branch of the United Steel Companies, Ltd., has recently completed the erection of a new wheel mill at The Ickles, Sheffield. The plant includes a double-acting ingot breaking machine, a 6000-ton forging press, a wheel rolling mill, and a 1500-ton dishing press, with other ancillary equipment. The output is stated to be between 3000 and 3500 solid wheels a week.*

THIS week we have had an opportunity to visit the new wheel mill which has been constructed at the Ickles Works, Sheffield, of the Steel, Peech and Tozer branch of the United Steel Companies, Ltd. The plant occupies an area of about three-quarters of an acre and has been equipped for the production of 180–200 solid wheels or discs per shift. The accompanying drawing shows the general arrangement of the plant, the principal items of the equipment being a horizontal double-acting ingot breaking machine, a coke oven gas-fired continuous furnace, a 6000-ton wheel forging press, a wheel rolling mill, a 1500-ton dishing press, and a walking beam heat-treatment furnace.




A—Ingot breaking machine
B—Block heating furnace
C—Scale breaker
D—Charging machines
E—6000-ton wheel press
F—Re-heating furnace
G—Wheel rolling mill
H—Motor house
J—1500-ton dishing press
K—Water spray treatment machines
L—Mono-rail jib crane
M—Transfer bogie
N—Hardening furnace
P—Tempering furnace

LAYOUT OF WHEEL PLANT



INGOT BREAKING MACHINE

The sequence of operations in the mill begins with steel ingots of the required dimensions and quality being delivered from the melting shop. They are laid out in rows for inspection, and each ingot is then divided into a predetermined number of equal-sized blocks. Prior to breaking, however, a series of nicks are burnt on the surface of the ingot, each of them extending round approximately one-third of the ingot circumference. These nicks are so spaced, by the use of an adjustable template, that each resulting block is of the correct weight to form a wheel. When this operation has been completed the ingot is lifted by a magnetic crane on to the bed of a horizontal double-acting ingot breaking machine which is capable of breaking 17in diameter ingots into lengths not less than 1¼ times their diameter. This machine, which was supplied by Crosthwaite Furnaces and Scriven Machine Tools, Ltd., Leeds, and which is illustrated herewith, consists essentially of a large crosshead supported on anti-friction rollers. The crosshead is actuated by a steel eccentric securely keyed to a high-tensile forged steel shaft, which is driven, through gearing, by a 100 h.p., 970 r.p.m. induction motor, which in turn drives by belt on to a large flywheel. A hand-operated clutch is provided for engaging the crosshead. The clutch is designed so that the machine stops at the middle of the stroke and it is thus not possible for it to stop with the crosshead in contact with the ingot. The main body of the machine carries two pairs of hard steel breaking blocks, which are adjustable to varying centres. They are also adjustable in height to give the correct setting for breaking the ingots.

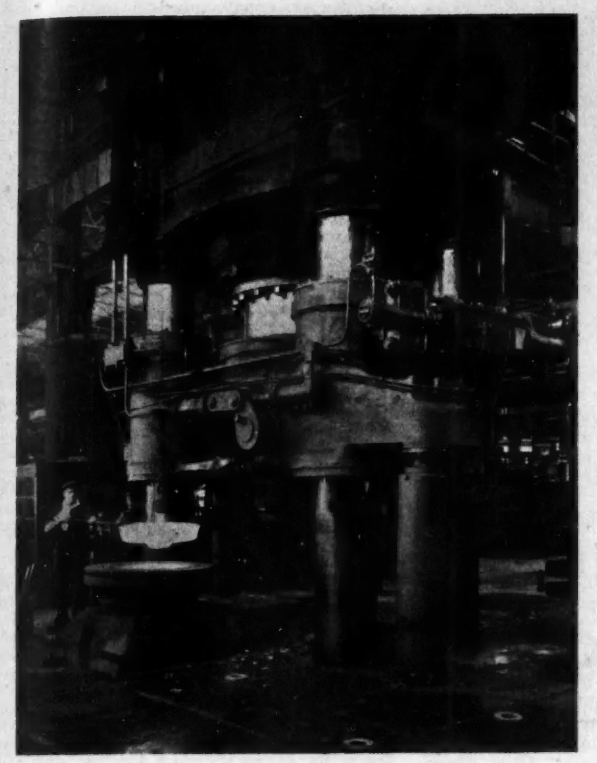
After the blocks have been broken, any surface defects which may be present are burnt out by a deseaming torch, and the blocks are then loaded on to the bogies of a continuous gas-fired counterflow furnace built by G. P. Wincott, Ltd., Sheffield. The furnace consists of a preheating zone to accommodate nine bogies, a heating and soaking zone to accommodate four bogies, and a cooling zone to accommodate two bogies. Each bogie normally carries nine blocks, and as thirteen of the fifteen bogies in the furnace at any one time actually carry the charge, the holding capacity of the furnace is 117 blocks. There are two bogie transfer cars, one at each end. The bogies are propelled through the furnace by an electrically operated double-rack pusher, which can exert a thrust of 20 tons and has a stroke of 9ft 6in. It is driven by a 30 h.p. d.c. motor. Limit switches are used for the transfer cars and for haulage of the bogies on the return track. During their passage through the furnace the blocks are thoroughly heated to a uniform temperature of approximately 1200 deg. Cent, a process which takes from five to seven hours. At the discharging end of the furnace each block is lifted from the bogie by a charging machine—described later in this article—and inserted in a whirling chain descaling machine which removes the scale from the top and bottom of the block.

### Wheel Forging and Rolling

After the blocks have been descaled they are transferred to the 6000-ton forging press, which is a single-cylinder, four-column machine operated by two 600 h.p. hydraulic pumps and an air-loaded hydraulic accumulator with a hydraulic intensifier. The press, which is shown in one of our illustrations, was supplied by Davy and United Engineering Company, Ltd., Sheffield. It has been specially designed for wheel forging, its equipment including hydraulic gear for moving the slabbing and finishing anvils in and out. There is also a hydraulically operated swinging holder for the top slabbing tool, which is pivoted on one of the columns, and mechanical handling gear for the wheel blanks. The gear consists of two gripping arms with forked fingers on the ends, working—one at each side—in the narrow space between the press columns. The gripped blank is lifted by the movement of the press crosshead, and as the gear is attached to the

crosshead the fingers grip the piece at a suitable height whatever its size. The fingers also form a convenient means of centering the piece under the press.

Power for the press is supplied by two 600 h.p. electrically driven horizontal three-throw hydraulic pumps having three rams, each 4½in diameter, 15in stroke, with a speed of 120 r.p.m., which are capable of a theoretical delivery of 280 gallons a minute against a working pressure of 3000 lb per square inch. Each group is driven through a double helical single reduction gear, the speed of the motors being 720 r.p.m. An air-loaded hydraulic accumulator, with the following characteristics, is included in the circuit: useful water capacity, 300 gallons; total volume of air and water, 520 cubic feet; air and water pressure, 3000 lb per square inch. The accumulator has two water bottles and five air bottles and the control gear is arranged for by-passing the water delivered from the pumps according to the position of the water in the accumulator, the pumps running continuously. A safety control is arranged to cut out the pumps at the high level and to shut the accumulator stop valve at the low level should the normal control instruments fail. A vertical intensifier low-pressure ram is operated through valves by the fluid medium from the air accumulator at 3000 lb per square inch maximum, to act on a high-pressure ram which intensifies its fluid medium to 6000 lb per square inch maximum, the high-pressure cylinder being connected with the main cylinder to the press. One of the photographs reproduced on this page shows the arrangement of the hydraulic pump and motor house. The electrical equipment for the whole plant was supplied by the British Thomson-Houston Company, Ltd., Rugby.



6000 TON WHEEL FORGING PRESS

The sequence of operations when a block reaches the forging press is, briefly, as follows. The block is placed on a slabbing anvil, which is then moved under the press. The top slabbing tool is next swung under the press and a light squeeze is made to break the scale, which is blown off by compressed air. The block is then pressed into a blank in a ring hanging from the top slabbing tool. The top slabbing tool is lifted and the blank is ejected from the ring by the press crosshead into the forming die which has been brought into position by the sliding table, after which the slabbing tool is swung away. The partly formed blank now being within the forming die, the crosshead carrying the top forming tool makes the final pressing. This last stroke is one in which the full power—6000 tons—of the press is brought into use. The forged wheel is punched and finally lifted by crane for transference to a coke oven gas-fired reheating furnace, capable of heating about thirty blanks an hour from 1100 deg. Cent. to 1250 deg. Cent.

Having been brought to the required temperature for rolling, the forged wheel goes to the vertical rolling mill, which has been designed for the production of solid wheels, from 18in up to 4ft in diameter, and up to 7½in face. The mill, which was supplied by Davy and United Engineering Company, Ltd., and which is illustrated below, is also suitable for producing gear wheels up to a width of 6½in on the rim. There are five rolls—two web, two side and one back—which combine to roll the wheel blank to the correct finished diameter and thickness, forming the tread and the rim at the same time. Each web roll assembly is moved in and out to the centre line of the mill by a ram and cylinder, the ram having an extended tail rod which is screwed and fitted with nuts to provide an accurate method of limiting the forward and return strokes. The back, or tread, roll is equipped with a similar ram and locking nuts. The wheel is supported in the mill by a mandril through the bore, two adjustable brackets supporting and holding the mandril upon which the wheel rotates during the rolling process. When rolling the wheel, it is essential that the web rolls move in towards each other at an equal rate, an operation which is accomplished by feeding each roll by a separate pump, special metering valves being provided to control the fluid so that the speed of the rams is accurately adjusted. The drive to the web rolls is taken through a universal spindle from a 500 h.p. variable-speed motor. On completion of rolling the wheel is transferred by a charging machine to a 1500-ton dishing press, which is a conventional forging press suitably modified to perform the dishing operation. It has a sliding table to bring the wheel under the centre line of the press crosshead, and its power is supplied by the pumps and air-loaded accumulator which operate the 6000-ton forging press.

Most of the solid wheels produced at the mill are rim-sprayed to give a hard wearing tread, in which process a wheel is first heated to a temperature of about 850 deg. Cent. in a walking beam furnace. The furnace is fired by twenty-eight low-pressure burners suitable for coke oven gas, and the hearth consists of a firebrick-lined bogie running on a series of cast iron turned rollers which are flanged on one side to give guidance. The bogie is built up of longitudinal joists supporting a platform of mild steel plates and side angles, and is caused to rise and fall by a double-acting cylinder which operates a push-pull rod attached to the lifting units. The cycle of operations, comprising up, forward, down and return movements, is automatic and takes about twenty seconds. The charging and discharging doors of the furnace are electrically operated and automatically

WHEEL ROLLING MILL

HYDRAULIC PUMP AND MOTOR HOUSE

controlled. On removal from the furnace the wheel is placed on a rotating table, on which it is spun for a predetermined time at a constant speed, during which operation the rim is sprayed by a series of fixed jets located round the circumference of the table. After heat-treatment the wheels are ready for inspection and machine.

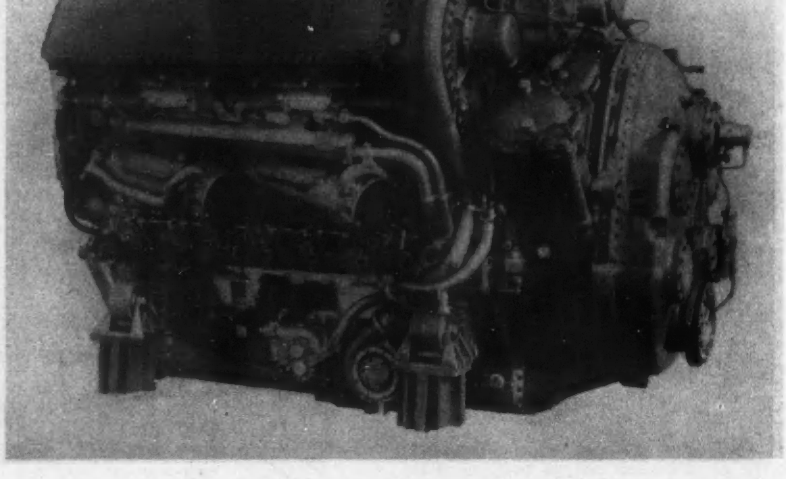
The new plant includes three charging machines, which have been supplied by Wellman Smith Owen Engineering Corporation, Ltd., Parnell House, Wilton Road, London, S.W.1. They are 25-cwt machines and in most respects are similar in design. The machine used for transferring the blocks from the furnace to the forging press has a span of 17ft, and the span of the wheel handling machines is 20ft. The slewing radii from the centre of the grips to the pins are 17ft and 18ft respectively, and the driving speed of all the machines is 400ft a minute. The trolley of each machine runs on a substantial underframe, which in turn is supported on four 1ft 9in diameter long-travel runner wheels revolving on fixed axles, two of the wheels being driven. The trolley wheels are supported on through axles, all wheels being driven. The roller path and centre pin bracket are mounted on the trolley frame, the revolving part of the machine turning on cast steel rollers. A ball bearing takes the down-weight thrust and also serves to locate the machine about the centre pin. The slewing frame carries the operator's platform, on which ample room is provided for all the controls and from which a good view is given of the load in all positions. Gripping of the blocks is effected by a motor-driven gear through a fluid coupling, which takes up the load gradually and stalls at maximum pressure. A cast steel charging bar carries the grips and can rotate through 360 deg. It is secured in a rocking frame which pivots on brackets forming the front part of the slewing frame.

## Admiralty Lightweight Diesel Engine

In presenting the Navy Estimates, the First Lord of the Admiralty announced that a special lightweight, high-powered diesel engine of advanced design had been completed and that successful trials had been held during the past year. He also stated that a programme of sea trials was being carried out and plans for large-scale production were being formulated. The engine in question is named "Deltic," and has been designed and developed for the Royal Navy by D. Napier and Son, Ltd., of Acton, on behalf of its parent, the English Electric Company, Ltd. The announcement of this new development was made by the Engineer-in-Chief of the Fleet, Vice-Admiral the Honourable Sir Denis Maxwell, K.C.B., during the course of his address, given last week, at the annual luncheon of the Diesel Engine Users Association, and mentioned in a Journal note in this issue.

Modern naval warfare calls for the increasing use of high-speed light displacement craft driven by engines of high power-weight ratio having low fuel consumption to enable the boat to have a large radius of action. During the last war no diesel engine was available which satisfied such requirements, so that petrol engines had to be employed and considerable fire risk and other limitations had to be accepted. The development of the light-weight "Deltic" diesel engine means that petrol engines need no longer be employed for high-speed craft, and a number of risks will disappear. Other advantages of the new engine are increased performance, improved reliability and reduced maintenance requirements.

We reproduce a photograph of the engine which gives a general idea of the new prime mover. Technical information made available by the Admiralty states that the engine is triangular in form with three crankshafts, and is of opposed-piston design operating on a two-stroke cycle. The power rating is up to 2500 b.h.p. Following shop trials the engine is undergoing sea trials in a modified ex-German coastal boat.



ADMIRALTY "DELTIC" ENGINE

## Technical Reports

*Report on Investigations into the Stress-Corrosion Cracking in Welded Gas Mains.* London: The Institution of Gas Engineers. Price 2s. 6d. The report by the British Welding Research Association, deals with the failures of welded mild steel work in gas-works and mentions that the majority occurred in plant treating gas from continuous vertical retorts. Investigations already in hand are mentioned, together with some proposed field tests. Accelerated laboratory experiments at Cambridge University are briefly mentioned and the work at King's College, Newcastle, undertaken as a result of a failure in a main carrying saturated crude coke oven gas, is described and illustrated. Tests carried out by the Appleby Frodingham Steel Company, Ltd., are recorded. Field tests were put in hand at Doncaster gasworks to determine that cracking of strained specimens could be obtained by gasworks liquor, and also at the Margam works of the Steel Company of Wales to test under industrial conditions the laboratory results obtained at King's College. The field tests are described, tabular statements are given and there are photographic and diagrammatic illustrations. Following some notes upon the discussion of the evidence the conclusions arrived at from the tests are listed. These state that the cracks are intercrystalline, associated with the welds and irregularities in the weld bead and start from the inside of the main. The failures are invariably located between the gas cooling plant and the ammonia washers and it appears that additional external stresses are necessary for failure to occur. Stress relief of weldments by heat-treatment gives immunity and the hot nitrate solution test is apparently satisfactory to determine the cracking susceptibility of steels. Shot peening and hammer peening appear to give immunity and low-temperature stress relief also gives a degree of protection.

*The Suction of Moisture Held in Soil and Other Porous Materials.* Road Research Technical Paper No. 24. London: H.M. Stationery Office. Price 2s. Movements of moisture in soil foundations may affect the stability of structures which the soil supports. These movements depend on the suction or reduced pressure at which the water is held in the soil. Ways of measuring the suction of moisture held in soil and other porous materials are described in this report. The importance of such measurements lies in the knowledge which they can give of the relationship between moisture content and suction. This enables an estimate to be made of the final moisture condition and strength which will be reached after movements of moisture have ceased.

The report describes detailed laboratory procedures for the nine principal methods of suction measurement, namely, the suction plate, tensiometer, centrifuge, pressure membrane, consolidation, freezing point depression, vacuum desiccator, sorption balance and electrical resistance methods. The range covered by each method is stated, and the methods can be applied not only to civil engineering problems, but to the study of soil in agriculture and to the behaviour of porous materials used in the ceramics industry.

# The Burning of Boiler Fuel in a Marine Diesel Engine

*For several years heavy fuel has been burnt by the main engine of the oil tanker "Auricula," after successful shore experiments carried out on a single-cylinder engine. Fuel of 1500 seconds Redwood I at 100 deg. Fah. was used for a long period, and during the last two years boiler fuels, having an average viscosity of 3320 seconds Redwood I at 100 deg. Fah., have been used successfully.*

In the last quarter of a century there has been a rapid change over from coal to oil fuel; to-day 83 per cent of the world's fleets burn oil as fuel, and of this total about 32 per cent, or 23,435,671 tons gross, are motor ships. These vessels burn expensive distillate fuel and for reasons of economy considerable attention has been paid in recent years to the possibilities of burning the less costly heavy fuels as burnt under boilers. Another factor influencing the trend towards using fuels of high viscosity is the change in the overall pattern of fuel consumption. Railway traction is employing more diesel engines, road transport is now almost exclusively powered by compression-ignition engines, agriculture is making increasing use of the oil engine, and auxiliary electrical generators are diesel driven, while in the air the gas turbine is reducing the demand for high octane petrol. The increasing consumption of distillates may affect refinery production and the availability of this grade of fuel. For the bunkering of ships it is essential that fuel, within the required range of viscosity, is available at all ports, so that for working reasons the ability of diesel engines to burn heavy oil is of considerable value and acts as a safeguard against the day when other forms of transport may be competing for supplies of diesel fuel.

Mr. John Lamb, the chief research and development engineer of the Anglo-Saxon Petroleum Company, Ltd., has been interested in the problem of burning boiler fuel in diesel engines for many years, and carried out shore experiments on a single-cylinder Hawthorn-Werkspoor engine before fitting the necessary equipment in a ship. The ship selected for the second part of the experiment was the "Auricula," an oil tanker of 12,634 tons deadweight, having a length of 482ft 6in, a breadth of 59ft 2½in, a depth of 34ft 10in, and a speed of 12 knots, and built by R. and W. Hawthorn, Leslie and Co., Ltd. The ship was propelled by a solid-injection, four-stroke, single-acting, under-piston supercharged diesel engine of Hawthorn-Werkspoor design having eight cylinders of 650mm diameter by 1400mm stroke, rated to develop 4000 i.h.p. at 115 r.p.m., and a cylinder compression pressure of 490 lb per square inch, together with a supercharge air pressure of 5·5 lb per square inch. Modifications were made in the fuel system to enable fuel of a maximum viscosity of 1500 sec Redwood I at 100 deg. Fah. to be burnt, the main additional equipment being a heater and De Laval centrifugal purifier and clarifier units arranged in series. Water and heavy solids are removed in the purifier and the finely divided solids are removed in the clarifier so that the fuel when delivered to the service tank has a low ash content.

## Experimental Results

In a paper, entitled "The Burning of Boiler Fuels in Marine Diesel Engines," read before the Institute of Marine Engineers on December 9, 1947, and recorded in our issue of December 12, 1947, Mr. J. Lamb gave full details of the initial experiments carried out on the single-cylinder engine at the St. Peter's Works of R. and W. Hawthorn, Leslie and Co., Ltd., and described the method of cleaning the boiler fuel. Included in the paper were the results of the early voyages and photographs illustrated the condition of fuel valves, pistons and exhaust valves.

During the next two years the ship continued to operate successfully on fuels ranging in viscosity from 1200 sec to 1500 sec Redwood I at 100 deg. Fah., and during the whole three years of service the ship covered 217,832 miles at an average speed of 11·46 knots, operated 18,692 hours at full power and visited 75 ports. Initially diesel oil was used when manœuvring in and out of port, but this practice was discontinued after a short time and high viscosity fuel was used exclusively.

During the period the average cost per ton of high viscosity fuel was 54·1s. compared with 90·7s. for diesel oil, and the saving effected in the operating costs of the ship by burning boiler fuel amounted to £7,734 per annum. This saving can be related to the cost of equipping a 4000 i.h.p. engine during construction, which was given as £5000, and the cost of fitting out existing ships which should not exceed £10,000.

The burning of residual fuel in the main engines called for the solution of major problems such as the assessment of the effects on the engine of the impurities in heavy fuel, the need to remove water and to reduce the ash content to a low value, and the development of a method by which the fuel could be atomised to ensure combustion within a time limit. The performance of the machinery of the "Auricula" over a long period indicated that the ship could operate successfully on 1500 sec fuel; experiments were started, therefore, to cover all fuels used at sea, ranging from 40 sec to 6560 sec. The experimental single-cylinder engine was again used and endeavours made to burn 3000 sec fuel. They were successful and a test under service conditions was arranged, the ship making a voyage burning fuel of 2920 sec Redwood I at 100 deg. Fah. An examination of the engine confirmed the success of the experiment and the ship began her next voyage with permission to accept fuel up to 3500 sec viscosity.

The results of the inspection of the engine after three years' service were given by Mr. Lamb in his paper "Further Developments in the Burning of Boiler Fuels in Marine Diesel Engines," which he presented before the Institute of Marine Engineers on April 11, 1950, abstracts of which appeared in our issue of May 5, 1950. The condition of the engine parts was discussed and illustrated by photographs and it was stated that the examination had revealed no signs of damage. Wear rates of vital parts were no greater than found in engines burning diesel fuel, that for the cylinder liner being 0·0039in per 1000 hours. Many fuel valve components were still in serviceable condition after 1500 hours, and needles were fluid tight at 400 lb per square inch, while exhaust valves showed no sign of wear or pitting either in the seat or face.

Since the last examination, two-and-a-half years ago, the ship has been operating on fuels within the range of 2000 to 3500 sec Redwood I at 100 deg. Fah., and while the ship was in dry dock for hull damage repairs the opportunity was taken to open up the engines and make another inspection. At the invitation of the Anglo-Saxon Petroleum Company, Ltd., we were able to visit the ship and see the condition of the various parts, which is little changed from that noted in 1949. The piston crowns were in excellent condition and the piston rings were quite free, while no sign of carbon deposit was observed in the ring grooves and the exhaust valve lids and seats also appeared to be in good condition.

All the fuel consumed by the main engine during the five and a half years in service has passed through the purifying system consisting of a De Laval purifier and a clarifier working in series at less than half the rated output, which removed about 12 lb of impurities from every 15 tons of 3000 sec fuel. No corrosion of the separator bowls has been observed. The fuel in the dirty oil tank is raised to 140 deg. Fah. and then passed to the primary heater, where its temperature is increased to 180 deg. Fah. before passing through the system to the clean oil tank, from where the surcharge pump delivers it to a secondary heater which raises the fuel to 210 deg. Fah., which is the injection temperature of fuel above 2500 sec viscosity. At this temperature the viscosity is about 165 sec and fuel is delivered to the fuel valve at a pressure of about 7000 lb per square inch by the fuel injection high-pressure pump, which works in conjunction with a Bosch pump, the latter acting as a spill valve.

The pistons are fitted with five pressure rings and one scraper ring; the rings used have been produced by six manufacturers and made of different materials having a Brinell hardness number varying from 160 to 230, including materials not usually adopted, such as stainless steel and ductile cast iron. The latter material is giving results which are distinctly promising. In September, 1949, the original liners in cylinders numbers 4 and 5 were replaced by one new standard liner and one chromium-plated liner, so that the effect of plating the bore could be observed and the wear rates of the two liners compared when working under exactly the same conditions of service. The liners have been gauged since the ship arrived in the Mersey, and the readings obtained are recorded in the following table:—

| Liner No. | Total full-power hours | Mean wear, mm | | Maximum wear per 1000 hours, mm | Remarks |
|---|---|---|---|---|---|
| 1 | 33,214 | Top ... ... ... | 3·39 | 0·10 | Original liner |
| | | Middle ... ... | 1·75 | | |
| | | Bottom ... ... | 1·37 | | |
| 2 | 33,214 | Top ... ... ... | 3·02 | 0·09 | Original liner |
| | | Middle ... ... | 1·96 | | |
| | | Bottom ... ... | 1·95 | | |
| 3 | 33,214 | Top ... ... ... | 3·29 | 0·09 | Original liner |
| | | Middle ... ... | 1·92 | | |
| | | Bottom ... ... | 1·92 | | |
| 4 | 14,522 | Top ... ... ... | 2·10 | 0·14 | Fitted September, 1949, for experimental purposes |
| | | Middle ... ... | 1·19 | | |
| | | Bottom ... ... | 2·25 | | |
| 5 | 14,522 | Top ... ... ... | 0·53 | 0·036 | Chrome-plated liner fitted September, 1949 |
| | | Middle ... ... | 0·28 | | |
| | | Bottom ... ... | 0·32 | | |
| 6 | 33,214 | Top ... ... ... | 2·68 | 0·08 | Original liner |
| | | Middle ... ... | 1·40 | | |
| | | Bottom ... ... | 1·22 | | |
| 7 | 33,214 | Top ... ... ... | 3·59 | 0·10 | Original liner |
| | | Middle ... ... | 1·78 | | |
| | | Bottom ... ... | 1·63 | | |
| 8 | 33,214 | Top ... ... ... | 3·49 | 0·10 | Original liner |
| | | Middle ... ... | 1·93 | | |
| | | Bottom ... ... | 1·75 | | |

In reviewing the figures given in the table, it should be taken into consideration that until adjustments had been made to ensure the correct combustion of boiler fuel, the engine operated under conditions which were not conducive to minimum wear. The wear rates per 1000 hours do not include harbour steaming, and, with the exception of liners numbers 4 and 5, average 0·0006in per million revolutions.

To ensure good results certain precautions are taken and it is the practice to warm up the engine, which is fresh water cooled, to above dewpoint. Steam is introduced to the header tank and the cooling water is circulated, by-passing the cooler, for a period of about four hours, so that the jacket temperature is raised to 130 deg. Fah. and that of the piston to 125 deg. Fah. With regard to other parts, practice varies according to the decisions of the chief engineer. Exhaust valves are sometimes changed every two months, but have given satisfactory service up to four months without cleaning, while inlet valves have functioned for as long as nine months, although a shorter period is desirable. It is of interest to note that none of the original valves have been renewed. The ship is provided with two sets of fuel valve nozzles, one set for fuels between 40 and 1500 sec, and the other for fuels between 1500 and 3500 sec Redwood I at 100 deg. Fah. All nozzles have eight holes, those for the lower viscosity fuels being 0·85mm diameter, while for the higher range of viscosity the diameter is 0·75mm. A change from normal procedure is the practice of having nozzles and needle valves reconditioned, after 2000 hours' service, by the makers. This ensures accurate finish and eradicates faults which are responsible for poor combustion, increased wear of cylinder liners and of piston rings.

During the period July 12, 1951, to March 31, 1952, the ship's log records the following:

| | |
|---|---|
| Distance covered by ship | 47,311 miles (nautical) |
| Engine distance | 51,895·5 miles |
| Average speed | 11·92 knots |
| Average slip | 8·8 per cent |
| Hours sea and harbour steaming | 4,253 |
| Revolutions between pilot vessels | 26,757,420 |
| Revolutions harbour steaming | 1,069,410 |
| Average revolutions per minute | 112·4 |
| Average i.h.p. developed | 4,120 |
| Fuel consumption per day | 13·16 tons |
| Average consumption, main engines | 0·298 lb/i.h.p./hr |
| Average viscosity of fuels used | 3,320 sec |

Since commissioning in August, 1946, the ship has accomplished the following:—

| | |
|---|---|
| Hours operating at full power | 33,214 |
| Revolutions, sea and harbour steaming | 213 million |
| Distance steamed between pilot vessels | 385,584 miles |
| Fuel consumed by main engine | 18,212 tons |

Efficient filtering is essential for the successful burning of high viscosity fuel, and experience with the "Auricula" has shown that the sulphur content of the oil has had no detrimental effects. During its five and a half years in commission the ship has bunkered in fifty-six ports, and the maximum sulphur content of the various fuels has not exceeded 3½ per cent, but from experience gained the company is prepared to accept fuels with a sulphur content up to 5 per cent.

The usual practice of the company is to dry dock its ships every nine months, but the "Auricula" has been dry docked annually. The period has been lengthened deliberately so as to refute any charge of nursing the ship, and for the same reason the main engine has been run at an average i.h.p. of 4120, which is 5 per cent above the usual service rating of 3900 i.h.p.

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INSTITUTION OF NAVAL ARCHITECTS.—The Institution of Naval Architects has accepted an invitation from the Associazione Italiana di Tecnica Navale to hold a joint meeting in Italy at the end of September. Meetings will be held in Genoa on September 25th, 26th and 27th, when two British and two Italian papers will be read, from September 28th to 30th, in Rome, when one British and one Italian paper will be read, and on October 1st and 2nd, in Naples. During the meetings visits to shipyards and excursions are being arranged by the Italian authorities.

## Short Notices

*Engineering Hydraulics.* Edited by Hunter Rouse. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 120s.—This volume is intended as a comprehensive reference work on the principles of hydraulics. Each of the chapters has been written by an American authority, and was submitted as an advance proof to the fourth hydraulic conference held at the State University of Iowa in 1949. The book has since been revised in the light of criticisms then received. It is a volume of about 1000 pages; the chapters and their authors are listed herewith: Fundamental Principles of Flow, H. Rouse; Hydraulic Similitude, J. E. Wornock; Flow Measurement, J. W. Howe; Hydrology, G. R. Williams; Flow of Ground Water, C. E. Jacob; Steady Flow in Pipes and Conduits, V. L. Streeter; Surges and Water Hammer, J. S. McNown; Channel Transitions and Controls, A. T. Ippen; Gradually Varied Channel Flow, C. J. Posey; Flood Routing, B. R. Gilcrest; Wave Motion, G. H. Keulegan; Sediment Transportation, C. B. Brown; Hydraulic Machinery, J. W. Daily.

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*Applied Electricity.* By H. Cotton, D.Sc., M.I.E.E. London: The Cleaver Hulme Press, Ltd., 42A, South Audley Street, W.1. Price 17s. 6d.—The subject of applied electricity is so well explored in the existing literature that the appearance of a new book requires some justification. This justification is given in the author's preface, which declares that the purpose of the book is: first, to provide a sound account of the basic principles on which the edifice of electrical practice is built, and, secondly, to cover the present requirements of examinations, particularly those of the subject of "Applied Electricity" for Part I of the B.Sc. (Eng.) degree of the University of London. The syllabus of this subject is very different from that for the old subject, "Electrical Technology." Before 1937, textbooks for this examination could be compiled on the assumption that the reader would already have the necessary fundamental knowledge of magnetism, electromagnetism and electrostatics, or would have access to separate works on the subject. Mr. Cotton's new book, however, is written in the belief that the student should have, in a single volume, all the information that he needs on a particular subject. Accordingly, the book opens with chapters dealing individually with the electric circuit, magnetism, electrostatics, conduction in electrolytes, and thermo-electricity before passing to the part of the subject that might be called applied technology. This portion of the book covers some 300 pages and, in fifteen chapters, deals with d.c. and a.c. rotating machines, electrical resonance, polyphase working the static transformer, electronics, illumination, measuring instruments and units and dimensions. A large number of worked examples and answers are given at the end of the book.

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*Principles of Lighting.* By W. R. Stevens, B.Sc., M.I.E.E., F.I.E.S. London: Constable and Co., Ltd., 10-12, Orange Street, W.C.2. Price 35s.—The aim of this book is to describe the principles of different kinds of lighting installation, giving contemporary examples of good practice. Most of the basic information on photometry and colorimetry that the lighting engineer is likely to require is compressed into the first five chapters, the last of which deals with artificial light sources. The rest of the book is devoted to the design of lighting fittings and the application of these fittings to a number of particular subjects, ranging from industrial lighting to the lighting of homes, offices, schools, theatres and motion picture studios. Road lighting, airport lighting, decorative lighting and floodlighting are also dealt with and there is a chapter on natural lighting. Throughout the text, the emphasis is on the method adopted and no detailed solutions of given problems are attempted. The author's reasons for this approach are, in his own words, that "much of what we do in lighting, we do because we did; and much because a given method seems to work although we are not sure why"; another reason is that the lighting engineer's tools, particularly light sources, are constantly being added to and improved, whence it follows that detailed solutions to specific problems might soon become out of date.

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*Tacheometry.* By F. A. Redmond. Surrey: The Technical Press, Ltd., Gloucester Road, Kingston Hill. Price 21s.—Most textbooks on surveying have a chapter about tacheometry, but this method of surveying is not as widely used as might be expected. The author of this book states that he knows of no general treatise on tacheometry, in which both the practical side of the subject and methods of measurement other than the stadia method are given adequate treatment. His object, therefore, is to encourage young surveyors to take a greater interest in tacheometry, and especially in that branch known as stadia measurement.

The general principles of stadia surveying, including the use of an inclined staff, are described after a general introductory chapter. There are then notes on some instruments which can be used for this kind of work, including, for instance, the "Microptic" theodolite, followed by a chapter on the probable errors in stadia work, and their relative importance. There is then a lengthy chapter on field work, followed by a complementary one on office procedures. The use of the plane table is then discussed. The next chapter is about the subtense method of measurement, which is described in some detail from both the theoretical and practical points of view; the tangential method is similarly treated in Chapter X. The last chapter is entitled "Special Instruments," and describes a few selected instruments and devices which have been designed for the purpose of either simplifying tacheometric measurement or making it more precise.

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*Prism and Lens Making: A Textbook for Optical Glassworkers.* Second edition. By F. Twyman, F.R.S. London: Hilger and Watts, Ltd., 98, St. Pancras Way, N.W.1. Price 58s.—The fact that two further impressions were required of the first edition of this book, which was published in 1943, indicates that it filled a gap in technical literature and was both authoritative and comprehensive. This is not surprising for few can be better qualified to write on the subject than Mr. Twyman, with his long experience in prism and lens making at the works of Hilger and Watts, Ltd. The new and enlarged edition of the book will be welcomed by all in the industry. Much of the information given is based upon work and processes not normally made available to others outside a manufacturer's factory. It is by the disclosure of the methods used in different establishments that industrial progress is accelerated and efficiency increased, for his initiative in this direction alone the author's work is much to be appreciated.

In his preface, Mr. Twyman points out that the scope of the new edition of the book has been extended to include information on the manufacture of spectacle lenses, fine dividing, and the working of large object glasses and mirrors. The making of artificial crystals and production of non-spherical surfaces are also dealt with. The space available does not permit a chapter-by-chapter discussion of the book, but under the following main headings each aspect of the subject is fully covered:—Single surface working; the nature of grinding and polishing; tools and materials in general use; dioptric substances; production of lenses in quantity; manufacture of spectacle lenses; microscope lenses; production of prisms in quantity; testing optical work; the Hilger interferometers for testing prisms and lenses and other interferometers; surface treatments; testing optical glass; annealing and normalising, and large object glasses and mirrors. All of the subject matter is amply illustrated with photographs, diagrams and drawings, and, in addition to a useful guide to recommended reference books on optics and optical glassworking, the book contains a comprehensive bibliography.

# American Engineering News

*(By our American Correspondent)*

## A High-Speed Crystal Clutch

As part of a project for the development of fast-acting clutches suitable for use in high-speed computers, an interesting experimental crystal clutch has recently been developed at the National Bureau of Standards. In the new clutch the application of a d.c. voltage to the electrodes of three "Bimorph" piezo-electric crystal elements causes bending of the elements; this bending presses the clutch output disc against the rotating input disc. Important properties of the crystal clutch are a high speed of response and an almost negligible current drain. No current flows, other than insulation leakage, after the applied voltage has charged the capacity of the crystals. The clutch therefore creates no magnetic field; this fact may be an advantage in certain applications. In the only clutch model thus far constructed the output shaft delivered useful torque in as little as 0·2 millisecond after voltage was applied. Output torque of the engaged clutch was approximately 16·5 ounce-inches at 400V excitation, or 21 ounce-inches at 500V. The no-voltage drag torque, however, was about 7·5 ounce-inches, a substantial fraction of the engaged torque.

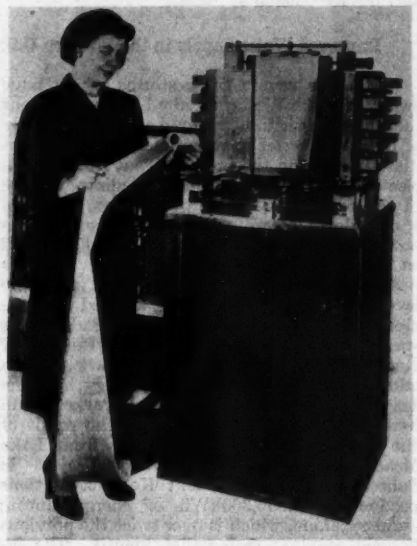
The construction of the crystal clutch is simple. The output disc is situated between two rotating members: a thin, flexible crystal pressure plate and a heavier mounting plate, or input disc. Three of the "Bimorph" crystal elements, which bend when opposite potentials are applied to different parts of the crystal surfaces, are spaced at 120 deg. intervals. When the exciting voltage is applied the crystals press against the pressure plate at a radius of 1·5in, pinching the output disc between the pressure plate and the input disc. The clutch proper and its immediate mounting occupy a space about 6in in diameter and a little more than 1in long. The complete assembly includes, in addition, internal bearings for the output shaft, bearings and mounts for the entire assembly, a drive pulley, and slip-rings for transmitting the exciting voltage to the rotating assembly. The clutch was tested for speed of response by placing the needle of an ordinary gramophone crystal pick-up in a small dimple in the clutch output shaft. By connecting the pick-up output to the vertical input of a cathode ray oscilloscope, and connecting the clutch excitation voltage to the horizontal input, the time lag between the application of the exciting voltage and the resulting motion of the output shaft was observed. Alternatively, by connecting the "Bimorph" terminals to the vertical plates of the oscilloscope it was possible to observe the voltage rise as the capacitance of the "Bimorph" crystals became charged.

Several factors enter into the design of a clutch of this kind. Speed of response, the principal design goal, is related to the inertia and loading of the output system, the available torque, the distance the crystal pressure point must move before it begins to pinch the output disc, and the resonant frequency of the crystal itself. It is the resonant frequency which sets the ultimate limit to the speed of response. The dimensions of the "Bimorph" crystal determine not only its resonant frequency, but also its sensitivity. The resonant frequency, in kilocycles per second, of a Rochelle salt crystal "Bimorph" is given by $26\,T/LW$ and the sensitivity in mils per kilovolt is approximately $0{\cdot}08\,LW/T^2$, where $L$, $W$, and $T$ are crystal length, width and thickness, in inches. Since increased crystal thickness is favourable to high resonant frequency, but unfavourable to high sensitivity, design dimensions must be matters of compromise and judgment. It has been found that if resistance is present in the excitation circuit, the voltage appearing across the crystals will rise exponentially while the crystal capacity (about 0·0065 microfarad) is charged. If the voltage rise is excessively slow, the speed of response will be impaired. It might be thought that if resistance were eliminated, so as to give a very fast voltage rise, the speed of response would be a maximum. This does not prove to be the case, however. Instead, an irregular output motion appears, believed to be due to the bouncing of the crystal against the output disc, while the response time shows no significant improvement.

Rochelle salt crystal elements are used in the present clutch because they are readily available and highly sensitive. Rochelle salt has several disadvantages, however: it is easily fractured, melts at 55 deg. Cent., and will deliquesce unless protected from humidity. It is believed that barium titanate crystals should provide a mechanically rugged clutch useable at temperatures up to 100 deg. Cent. Barium titanate is less sensitive than Rochelle salt, however, and also has a higher capacity.

## A High-Speed Automatic Typewriter

The accompanying engraving shows an interesting automatic "typewriter," which has been developed by the Potter Instrument Company, of Great Neck, New York, for applications in the fields of computing, data-handling and communications. The machine has a particularly simple printing mechanism, which is capable of reproducing 24,000 characters per minute. A total of forty-seven characters, comprising the alphabet, numerals, and special other symbols are employed. A line at a time is printed using ordinary paper, standard typewriter ribbon, and hard-face type. The main



HIGH-SPEED AUTOMATIC TYPEWRITER

portion of the equipment is an electronic serial-parallel storage unit. This accepts information in the form of coded pulses from an external source, such as a computer, a magnetic tape, punched cards, communication lines, &c. There are eighty channels corresponding to the characters per line, and information is alternately stored and extracted in these channels, completing a cycle once for each line printed. The type is arranged in segments about the periphery of an 8in diameter disc rotating in a horizontal plane at the rate of 300 r.p.m. Eighty hammers arranged in an arc parallel to the type wheel are moved by impulses at appropriate times against the type faces according to instructions received from the electronic storage. The impression is registered on regular paper which is fed intermittently upward from a roll, and which conforms to the curve of the type wheel. A photo-electric pulse generator on the shaft of the print wheel is used to release the characters out of the electronic storage. The system is self-synchronous, and can be operated on a continuous or intermittent basis. The electronic storage unit, which is essentially an extremely flexible shift register, may be used as part of a computer to perform addition, subtraction, division, and multiplication. It may also be used to shift the information being printed to any selected columns. A facility that is believed to be of particular advantage in communications, is that the machine can be fed serially over a channel of telegraph band width. The printing can be controlled by the input to be intermittent or continuous. It has been suggested that the machine will find wide application where mass filing of information on business machine cards and magnetic or punched tape calls for convenient and extremely rapid access and translation.

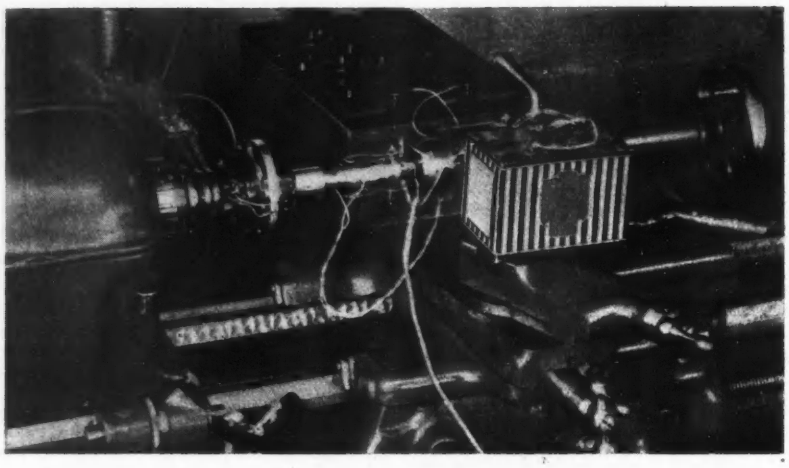
## Construction of an Intermediate Reactor for Submarines

The U.S. Atomic Energy Commission has authorised the immediate construction at West Milton, New York, of the land-based prototype of an atomic power plant for submarines. The design and construction of this nuclear reactor has been under the direct supervision of the Knolls Atomic Power Laboratory operated in Schenectady, New York, by the General Electric Company for the Commission. The reactor will be situated on a 4000-acre site, already owned by the A.E.C. in West Milton, near Schenectady. The prototype will be used for final development work leading to the construction of an intermediate energy reactor for propulsion of a submarine. The Electric Boat Company, of Groton, Connecticut, is associated with the General Electric Company as the submarine builder on this project and is also serving in a similar capacity on a prototype reactor of different design which is being constructed by the Westinghouse Electric Corporation at the National Reactor Testing Station in Idaho. During all the phases of design of the West Milton project, careful attention has been given to the safety of the operating personnel and off-site areas. The reactor will be housed in a steel sphere, 225ft in diameter, which will be similar to structures widely used in the chemical and petroleum industries. This special design of reactor building is being developed to provide, during preliminary test operations, protection additional to the many safety controls of the reactor itself. The land-based prototype at West Milton is expected to contribute research, development and operating data required for the design of future reactors for producing industrial and commercial power.

## Response Time of Magnetic Fluid Clutches

Recent work at the National Bureau of Standards has indicated that the response time of the "NBS" magnetic fluid clutch can be reduced to the order of 1·5 milliseconds to obtain an output equivalent to 63 per cent of the maximum torque. It will be recalled that the "NBS" magnetic fluid clutch was invented by Jacob Rabinow, of the Bureau, in connection with the active electronic digital computer programme of the National Bureau of Standards, primarily to meet the need for a fast-acting start-stop computer input mechanism. The distinctive property of the clutch is the use of a magnetic fluid, consisting of a mixture of iron particles and oil, to couple the rotating input member to the output member. When a magnetic field is applied to the fluid the mixture virtually solidifies, binding the input and output members together. If other factors are kept constant the torque developed by such a clutch appears to be proportional to the magnetic flux, which is, in turn, a function of the exciting current. Experience has made it clear that the magnetic circuit of the clutch should be laminated for fastest response; otherwise current, flux and torque will be slow to build up because of eddy currents. Analysis shows that the torque-to-inertia ratio will be a maximum and, thence, will facilitate fast response, if the inertia of the clutch output disc equals three times the load inertia. The ultimate natural frequency and the response speed will generally be determined by the iron-oil mixture and the gap width in the magnetic circuits.

Two clutch models were studied in the response time investigation of the N.B.S., both being of a design having a thin, flat output disc attached to the output shaft. The two clutches



MEASUREMENT OF RESPONSE TIME OF MAGNETIC CLUTCH

were almost identical in construction, except that one was made with a laminated magnetic circuit to reduce eddy currents, while the other was of unlaminated construction and had an output shaft of larger diameter. The response time was determined by mounting the clutch model in a lathe, fastening a strain gauge to the output shaft and connecting the electrical output of the strain gauge to the vertical input of a cathode-ray oscilloscope. By starting the horizontal sweep of the oscilloscope simultaneously with application of the clutch excitation voltage a trace of output torque versus time was obtained. Besides these torque time determinations, some displacement time tests were made, and also some steady-state measurements of torque versus current. The response time of the laminated clutch was found to be limited only mechanically, while response of the unlaminated model was limited by eddy currents; because of the latter, the magnetising current and the output torque were slow to build up. The output torque of the laminated clutch oscillated considerably for several milliseconds after the application of voltage. Since the output system of the laminated clutch could be stiffened by using a larger diameter output shaft, and since the elasticity of the strain gauge shaft would be eliminated in practical applications, the amplitude and period of oscillation of the disc and shaft output system could be made negligibly small in practice. The rise in output torque would then be approximately exponential. Assuming ideal mechanical resistance and stiffness, maximum response speed can be obtained by employing a certain torque-to-inertia ratio. It can be shown that this calls both for the above-mentioned 3 to 1 ratio of disc inertia to load inertia, and for driving the magnetic circuit to saturation as rapidly as possible.

The clutches studied gave torques of about 7·5 lb-in with 250 ampere turns of magnetisation. Indications are, though, that the number of ampere turns could be quadrupled without either fusing the coils or saturating the magnetic circuit. This would give a maximum torque of 30 lb-in. To drive the clutch to this value with a time constant of 1·5 milliseconds, 1·0A would have to be supplied to the coils from an 800V source in series with an 800Ω resistor, or from an equivalent circuit. In a practical installation a high-voltage pulse would be used to supply, for only a few milliseconds, the large amount of power needed to get the load up to speed rapidly; the power would then be reduced to give a torque just sufficient to overcome the friction of the load. For fast stopping and reversing, as well as starting, two of the clutches can be connected so as to apply torque in either direction when the appropriate clutch is energised. The study has indicated that when the current supplied to the clutch is cut off the torque decreases to the de-energised value at least as fast as it built up; thus a load can probably be stopped about as quickly as it can be brought up to speed. More remains to be learned about some aspects of the response time of the "NBS" magnetic fluid clutch. It is hoped that future work will centre on the transient transfer of power through the iron-oil mixture. Such work is intended to include an analysis of the effects on the response time of (1) the fluid gap width, (2) the ratio of iron to oil, (3) the iron particle size, and (4) the viscosity and surface tension of the oil.

### Improved Water Supply in the Western U.S.

The severe snow storms which have swept over the Western United States in recent months have virtually assured a plentiful supply of irrigation water next summer, and an immediate increase in the power output from hydro-electric power stations. An immediate increase in the production of energy has resulted from a drawdown of water stored in reservoirs in anticipation of a heavy spring run-off as well as from an increased winter flow. This is particularly the case at Hoover Dam, where the level of Lake Mead is being lowered in anticipation of one of the largest Colorado River spring run-offs on record. The Bureau of Reclamation anticipates the generation of an additional 750,000,000kWh of energy by June 1st at the Hoover, Davis and Parker Dam hydro-electric power stations, as the result of the increased discharge of water from Lake Mead. On the Central Valley Project in California, the Shasta and Keswick stations produced 289,856,300kWh of energy during January alone, which is over twice the previous average production for that month. The increased production resulted not only from a drawdown in the level of Shasta Lake but also from an increased flow resulting from greater precipitation at the lower levels. The combined generating peak of these two plants during January was 540MW, which is one-fifth of the total generating capacity of all power stations in northern California. Irrigation farmers in all contracting districts along the Friant-Kern and Madera canals of the Central Valley Project have been advised that they may anticipate a full water supply. The level of Franklin D. Roosevelt Lake, behind Grand Coulee Dam on the Columbia Basin Project in Washington, is also being taken down several feet, in anticipation of an unusually high spring run-off when snow stored in the mountains starts to melt.

### Electric Power from Atomic Energy

A rather guarded announcement by the U.S. Atomic Energy Commission has now disclosed that useful electric power was for the first time produced from atomic energy at a recent demonstration at the National Reactor Testing Station, near Arco, Idaho. Heat energy was removed from a breeder reactor by a liquid metal, and this energy produced enough steam pressure to drive a turbine. The turbine, in turn, generated more than 100kW of electric power, an output which was maintained for more than an hour.

## French Engineering News

*(By our French Correspondent)*

Electricité de France has announced that a second turbo-alternator set is now in service at the Chastang hydro-electric scheme in the Massif Central. Production at Chastang will be 500 million kWh per year.

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The electrification, modernisation and rationalisation of the French coal mines continues. From the north it is reported that at Ognies electricity has now replaced steam power. Certain seams have been closed but production has been increased at others. The overall production has increased from 2000 to 3000 tons. New plant has been installed in the Henin-Lietard mines and the quality of coal from these mines is expected to improve considerably. At Lens a new system of roof supports is being tried out in which the roof is supported by metallic sheets and stanchions.

Because of the importance of coal, capital investments are unlikely to be limited in the same way as for other construction. For 1952 some 105,867 million francs will be spent: 28 millions will be used for general improvements and 16 millions on modernisation projects. The French Coal Board is certain that these investments will result in a general increase, bringing French coal production to 56·4 million tons per year. In 1951 France mined just over 53 million tons. In 1952 it is estimated that 74 per cent of the work will include the opening of new seams and general modernisation. Coke production should reach 4,800,000 tons a year in 1952 under expansion envisaged by the French Coal Board.

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A new oil refinery will come into operation at Ain-Taya, Algeria, this year; it will be able to treat from 100 to 200 tons of crude oil daily. Some material imported from Austria is being used in its construction; 7000 to 8000 cubic metres of oil storage is to be provided, and oil from Algerian wells will be refined.

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It has been announced that the first turbo-alternator set installed in the power station of the big Donzere-Mondragon hydro-electric scheme has undergone limited tests. The 70,000 h.p. turbine will operate under a 15m head. A second set will be tested under the same conditions shortly. The first two sets will come into operation at the beginning of the summer. Eventually there will be six sets, and about 1980 million kWh will be generated annually.

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The French Ministry of Marine has published figures of the French merchant fleet. It now comprises 726 vessels with a total tonnage of 3,173,224. This does not include a fleet of small specialised craft. Some 22 per cent of the total tonnage is in tankers. It also includes 281,000 tons of new shipping added in 1951, most of which was built with special war damage credits. Another 70,000 tons will be built to complete this work. The Ministry states that there are 650,000 tons being built. This total shows a great increase on the pre-war French fleet.

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The twenty-fifth annual congress of the Foundry Association will take place in Lille from May 19th to 21st. Some seventeen papers will be read, including several by foreign delegates.

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A programme of mineral exploitation for Morocco in 1952 has been published by the authorities. It includes expenditure of some 360 million francs and 270 million respectively to increase output from two series of coal mines in the Atlas Mountains. Prospecting for petrol will also be carried out. The Sté. Cherifienne, for example, hopes to be able to increase its production by at least 80,000 tons per year. The Government will finance these developments to the extent of about 300 million francs; the rest will come from banks and private sources.

# Industrial and Labour Notes

### Engineering Wages

At the end of last week it was announced that agreement had been reached between the Engineering and Allied Employers' National Federation and the Confederation of Shipbuilding and Engineering Unions on a claim for increasing the pay of engineering apprentices. Wage increases ranging from 5s. 6d. a week for apprentices aged fifteen to 11s. a week at the age of twenty are to come into operation as from Monday next, April 28th.

A special meeting of the executive council of the Confederation of Shipbuilding and Engineering Unions was held in London last week to discuss wages in the engineering, shipbuilding and ship repairing industries. There are thirty-seven unions in the Confederation, and it is understood that at last week's meeting it was decided to advance a fresh claim for a "substantial increase in wages." It will be recalled that the last general wage increase in the engineering, shipbuilding and ship repairing industries took effect last November and amounted to 11s. a week for adult male time-workers and payment-by-result workers, with corresponding increases for other workers.

### Railway Wages

According to a statement in last week's issue of *The Railway Review*, which is the official organ of the National Union of Railwaymen, a further wage increase is to be sought by railway workers. The statement says that "we are witnessing to-day demands being made in many industries for increases in wages," and adds that the National Union of Railwaymen is compelled to "go forward" if it is not to see a permanent lowering of the standard of life of British railwaymen.

The statement goes on to say that the N.U.R. executive committee has considered the very many resolutions from its branches all over the country and has decided to submit an early claim to the various executives of the British Transport Commission for an improvement in wages. In the statement it is emphasised that "it is absolutely imperative that there should be the maximum amount of unity," and with that end in view the N.U.R. executive says that it has requested a joint meeting with the executive committees of the Associated Society of Locomotive Engineers and Firemen and the Transport Salaried Staffs Association.

Railwaymen received two wage increases last year. In January, 1951, revised weekly rates and a new standard classification of grades came into operation for employees of British Railways, resulting in increases varying from 3s. 6d. to 13s. 6d. a week for men in the conciliation grades. For railway workers employed by London Transport the existing standard rates were increased by approximately 7½ per cent, or from 7s. 6d. to 11s. 6d. a week for adults, according to grade. Later in the year—from September—railway workers in both groups received further increases of approximately 8 per cent.

### The Steelfounding and Dropforging Industries

The Anglo-American Council on Productivity is preparing a series of statements setting out evidence of the value gained from visits of productivity teams to the U.S.A. and from the reports subsequently made by those teams. The first of these statements, dealing with the steelfounding and dropforging industries, have been issued this week.

Productivity teams from both industries went to the U.S.A. in 1949. The report of the steelfounding team was published later in that year and the dropforging report appeared in May, 1950. Both teams agreed that the best companies in this country compared very well with the best in the U.S.A., though they suggested that the average there was higher than here. The Council's statement says that the British Steel Founders' Association considers that productivity in steelfounding has increased by 15 or 20 per cent since 1949. In dropforging also—at least until the recent restrictions of steel supplies—productivity has increased by about 10 per cent overall. But, the statement adds, in neither industry are there industry-wide records of production and manpower from which productivity figures might be deduced, though the respective trade associations are investigating how to evaluate more precisely the trend of productivity. A number of individual forges and foundries, however, have reported significant increases in productivity, which, the Council says, are clearly in part the result of changes made in accordance with the teams' recommendations.

Another matter mentioned in the Anglo-American Council's statement is that both the steelfounding and dropforging reports have been fully discussed at conferences called by the appropriate trade associations and at a large number of meetings throughout the country. Furthermore—as has already been reported in our columns—the British Steel Founders' Association has set up a research and development division. The Anglo-American Council on Productivity takes the view that much has been done already in both industries, but it suggests that "it will be many years before the full effects of these novel visits overseas have been felt." What is important, the statement concludes, is that so much is taking place in the steelfounding and dropforging industries in line with the recommendations of the teams' reports and with the purpose of increasing productivity. In general, it is asserted, the influence of the reports has been "to encourage, to enthuse and to spur on action already pondered or begun."

### American Steel

When the House of Commons reassembled after the Easter recess on Monday last, the Minister of Supply, Mr. Duncan Sandys, was again questioned as to what quantities of steel had been received against the American purchase of 1,000,000 tons. He stated that, at the end of the first quarter of this year, about 172,000 long tons of steel, pig iron and scrap for Britain had been delivered at works in the U.S.A. or at other sources of supply and of that quantity 85,000 tons had reached the United Kingdom. It was expected, the Minister said, that deliveries at the source of supply would be completed by the end of 1952 in accordance with the agreement.

The Minister was then asked if, in view of the existing uncertainty in the American steel industry and its possible effect on steel deliveries to this country, he would reopen negotiations with the United States authorities to allow us to purchase ore and scrap direct from Germany and Sweden instead of indirectly through the U.S.A. In reply, Mr. Sandys said that so far as we were getting additional ore from those countries as a result of the American steel agreement, we were receiving it direct. What was happening was that American buyers were holding off and thus making more ore available for purchase by the United Kingdom.

### Stock Control and Storekeeping

The British Institute of Management has just published a revised edition of its booklet entitled *Stock Control and Storekeeping*, which is based on B.S.S. 1100, and which has been written primarily for the guidance of smaller firms. It is urged that careful stock control and a "live" storekeeping policy can do a great deal to avoid heavy capital investment in stocks and to assist the achievement of higher productivity.

The booklet describes a system of stock control which, it is claimed, should make periodical stocktaking unnecessary if it is properly enforced. The subject is dealt with under the following headings: the purpose of stock control; mechanics of stock control; accounting and mechanisation; storekeeping; stores organisation; storage and materials handling equipment; and selection and training of staff.

It is pointed out in the introduction to the booklet that material shortages of one kind and another seem likely in this country for some years to come. Where they exist, or where economic buying depends upon taking advantage of a temporarily favourable market, an orthodox system of stock control based on maximum and minimum stocks is difficult to operate, there being a tendency for some materials to be overstocked for long periods while supplies of others are awaited. Many firms to-day, the booklet says, are gearing their planning and purchasing to the materials most difficult to obtain, and buying the more readily available materials in the required proportions when they are sure of their key supplies. If that is done, the booklet shows, the inventory can be kept within bounds.

The booklet, price 5s., can be obtained from the British Institute of Management, 8, Hill Street, London, W.1.

### Scottish Management Conference

This weekend the British Institute of Management is holding its first Scottish conference at Gleneagles Hotel, Perthshire. The theme of the conference is "Management for Recovery," and the opening address, entitled "The Economic Background," will be delivered this (Friday) evening by Mr. George Schwartz. To-morrow, the speakers include Mr. B. A. C. Hills, on "The Principles of Economic Manufacture"; Mr. Ian Morrow, on "Management Accounting"; and Sir Richard Lloyd-Roberts, on "The Human Factor in Management."

### Industrial Productivity and Flexibility

The Chancellor of the Exchequer, Mr. R. A. Butler, has addressed a message to industry, which is included in the latest issue of the Government bulletin *Target*. It stresses the need for higher productivity and greater flexibility in industry. The Chancellor says that three major problems at present facing industry are that new investment must be kept back as more machines must go to pay for our basic needs of food and materials; steel is still in short supply; and exceptional changes in the patterns of manpower and production are required, not only by rearmament, but also by the need to increase exports outside the sterling area. A fourth difficulty, the Chancellor continues, might be listed, which is not as immediate as the other three, but is of great importance for the future—the growth of skilled and effective competition from Germany and Japan.

Mr. Butler's message goes on to ask how we react to these difficulties. Do we give them best by arguing that we are too heavily handicapped to make it worth while tackling the task of raising productivity? Or do we say that just because some things are working against us there is all the more need for extra effort to make headway? These questions, the Chancellor suggests, have only to be put to be answered. Throughout this country's history, he says, difficulties have not been treated as final obstacles, but as spurs and opportunities. The most recent example in his view is the remarkable ingenuity and courage with which industry has surmounted many raw material shortages which a year ago threatened to be so formidable. It is therefore more important than ever, the message concludes, for industry to make the best of the machinery that is available, to get the best out of fuel and raw materials, and to use to the best effect—and without avoidable waste—the nation's manpower resources.

# Notes and Memoranda

## Air and Water

ENGLAND-BELGIUM AIR FERRY.—The first air ferry to link England and Belgium opened on April 14th, when Silver City Airways started a vehicle-carrying service between Southend and Ostend. Bristol freighter aircraft, which operate the service, can carry two cars, a few motor-cycles and cycles, and twelve passengers in the rear of the aircraft. The 100-mile flight takes thirty-five minutes.

ALUMINIUM ALLOY LAUNCH.—An aluminium alloy tender, built in the "two-way tension" method of construction by Grimston Astor, Ltd., of Bideford, has completed acceptance trials for the Royal Navy. The launch, which is 26ft in length, has a draught of less than 18in and is powered by two Parsons C.4.M. Ford motors, each developing 22 h.p. at 2600 r.p.m. and driving 9½in diameter propellers.

THE NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—At a general meeting of the N.E.C. Institution of Engineers and Shipbuilders, held last week, Lieut.-Colonel Thomas Eustace Smith, joint managing director of Smith's Dock Company, Ltd., was elected president in succession to Sir Philip B. Johnson, and the following vice-presidents were elected: Mr. J. Leslie Batey, Mr. G. R. Edgar, Mr. J. B. Kerr and Mr. R. C. Thompson.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—The Institution of Engineers and Shipbuilders in Scotland has elected Sir William Wallace, the chairman and managing director of Brown Brothers and Co., Ltd., Edinburgh, as president in succession to Sir Andrew McCance, the deputy chairman, and joint managing director of Colvilles, Ltd. The two new vice-presidents are Mr. John Brown, naval architect of John Brown and Co., Ltd., and Mr. A. R. Mitchell, naval architect of Yarrows, Ltd.

DECEMBER AIR TRAFFIC.—During December, 1951, the airways corporations and associates had a total revenue traffic exceeding 13 million short ton-miles. Passenger traffic accounted for 8 million short ton miles, freight almost 3 million, and mail 2 million. On B.O.A.C. services over 2¼ million aircraft miles were flown, while seat miles available rose to over 93 million. Passenger miles flown exceeded 58½ million. B.E.A. carried nearly 63,000 passengers, an increase of 32 per cent over December, 1950, and the revenue passenger load factor rose from 50 per cent to 63 per cent. The activities of B.O.A.C. were seriously reduced by a labour dispute in December, 1950.

## Miscellanea

CORRECTION.—In the article which appeared in our issue of April 18th last, describing a transfer gearbox machine at the works of Morris Motors, Ltd., an incorrect impression was given of the actual machining time for each gearbox casting. On the machine a gearbox is completed every eighty seconds.

A STEEL SHEET PILING SECTION.—We are informed by the Appleby-Frodingham Steel Company, Scunthorpe, Lincolnshire, that it has added a new section to its range of steel sheet piling sections. The new section has a minimum thickness of 0·45in with a lock centre of 15¾in, is 10¾in deep with a weight of 40·98 lb per square foot of piling wall and a modulus of 43·75 cubic inches per foot of wall.

TRAINING COURSE FOR INDUSTRIAL DIESEL USERS.—A technical course on the operation and maintenance of industrial diesel engines has been introduced in the customers' training school of Leyland Motors, Ltd. A sectioned 0·600 type vertical diesel engine of 125 h.p., as well as various types of engine auxiliaries fitted to industrial units, have been installed in the school for instructional purposes.

BUILDING LICENCES AND MACHINERY INSTALLATION.—The Ministry of Works has announced that arrangements can now be made for building maintenance licences to cover minor works of alteration consequent on the installation of new machinery and on the transfer of machinery from one factory to another, besides, as hitherto, on transfers in the same factory. Current licences will be amended on application to the Ministry's Regional Licensing Officers.

ALUMINIUM DEVELOPMENT ASSOCIATION.—At the annual general meeting of the Aluminium Development Association, held on April 18th, Mr. H. G. Herrington, the managing director of High Duty Alloys, Ltd., and director of the Aluminium Wire and Cable Company, Ltd., was elected president, in succession to Mr. Austyn Reynolds. Mr. R. D. Hamer, a vice-president and director of Aluminium Laboratories, Ltd., was appointed vice-president and Mr. G. W. Lacey, sales director of the British Aluminium Company, Ltd., was elected chairman of the executive committee of the Association.

AGRICULTURAL ENGINEERING SCHOLARSHIP.—A scholarship, to be known as the Farm Mechanisation scholarship, has been donated by the publishers of *Farm Mechanisation* to the Institution of British Agricultural Engineers and will be applied for the benefit of students who experience financial difficulty in completing the final year of their study for the National Diploma in Agricultural Engineering. Full particulars, together with forms of application, may be obtained immediately from the Secretary, Institution of British Agricultural Engineers, 24, Portland Place, London, W.1. The closing date for receiving applications is May 15th.

AN APPRENTICES' CONFERENCE.—The third annual conference for apprentices in industry, organised by the Industrial Welfare Society, is to be held at Keble College, Oxford, from September 4th to 8th and September 9th to 13th. The conference is being duplicated in order to accommodate all who wish to participate in it. The general theme of the conference is "The Approach to Industrial Responsibility," and the aim is to foster among apprentices an awareness of their future industrial responsibilities as members of management, technicians or as worker representatives. Full particulars of the conference can be obtained from the Industrial Welfare Society, 48, Bryanston Square, London, W.1.

A CONFERENCE ON THE HYDROLOGY OF ARID ZONES.—Twenty-seven scientists from fifteen countries are to meet in Ankara, Turkey, from April 25th to 29th, to discuss problems of the hydrology of the arid zones, with special reference to underground water. This is the first meeting of its kind to be held in the Middle East, where these problems are acute. The subjects to be discussed include the physical and chemical properties, as well as the statics and dynamics of underground water; the hydrological balance and the influence of utilisation of underground water upon it; prospecting for underground water and adaptation of drilling methods to local conditions, and the relationship between the hydrology of underground water and other sciences. The proceedings of the symposium, for which Unesco and the Turkish Government are acting as sponsors, will be published in English, French, Spanish and Arabic.

A GLASS/RESIN PLASTICS CONVENTION.—We are informed by Fibreglass, Ltd., that it has organised a convention to be held on May 13 and 14, 1952, to consider glass-reinforced plastics. The purpose of the convention is to discuss on the widest possible basis the manufacture, application and future of these new structural materials. Amongst the 160 delegates there will be representatives from all glass-fibre manufacturing firms, from resin manufacturing firms and from research departments of industry and the services. Sir Hugh Chance, chairman of Chance Brothers, will preside. Mr. Clare Bacon, manager of the plastics section of the research development and engineering laboratories of the Owens-Corning Fiberglas Corporation, is coming over to read two papers, one on "Methods of Manufacture in the U.S.A.," and the other on "Applications of Glass/Resin Laminates in the U.S.A." British authorities will present papers on the manufacture of resins, glass-fibres and glass/resin products.

WORCESTER FIRM'S JUBILEE.—The firm of Heenan and Froude, Ltd., Worcester, has recently celebrated the fiftieth anniversary of its incorporation. The late Mr. Hammersley Heenan actually founded the firm in 1880, subsequently taking into partnership Mr. R. Hurrell Froude, the eldest son of the late William Froude, F.R.S., the inventor of the hydraulic dynamometer which bears his name. The resulting company was established under its present title in 1902. To commemorate the jubilee, an illustrated brochure has been prepared setting out the development and present activities of the firm and its several subsidiary companies, which have been acquired in recent years. In its earlier days Heenan and Froude, Ltd., specialised in the building of bridges and other steel structures. The Froude dynamometer, however, soon became its principal product, later activities including the manufacture of water and closed air circuit coolers, and automatic machines for the wire, strip and chain industries. Another important side of the firm's busine its manufacture of refuse disposal plants and incinerators. Its subsidiaries now include Associated Locomotive Equipment, Ltd., W. G. Bagnall, Ltd., Court Works, Ltd., Fielding and Platt, Ltd., Hyganic Developments, Ltd., Industrial Waste Eliminators, Ltd., Morton Machine Company, Ltd., and New Destructor Company, Ltd., whose products are all mentioned in the jubilee brochure.

## Personal and Business

PROFESSOR W. J. KEARTON, M.I.Mech.E., has been elected president of the Liverpool Engineering Society.

F. J. EDWARDS, Ltd., 359-361, Euston Road, London, N.W.1, will shortly open new premises in Park Street, Islington.

THE COLONIAL OFFICE announces the appointment of Mr. T. C. N. Pratt, A.M.I.C.E., as executive engineer in the Public Works Department, Sierra Leone.

Mr. F. G. GRIGG, 37, Isleworth Road, St. Thomas, Exeter, has been appointed to the staff of B. H. Chemicals, Ltd., Abbey Road, London, S.W.19, as representative in the south-western area and South Wales.

MATTHEW HALL AND CO., Ltd., 26-28, Dorset Square, London, N.W.1, states that Mr. J. Searle, formerly manager of its Manchester branch, has been appointed manager of the new branch in Southern Rhodesia.

INSLEY (LONDON), Ltd., 119, Oxford Street, London, W.1, has been appointed agent in the United Kingdom for the ball and roller bearings made by the Kaydon Engineering Corporation, Muskegon, Michigan.

HACKBRIDGE AND HEWITTIC ELECTRIC COMPANY, Ltd., Hersham, Walton-on-Thames, Surrey, announces that Mr. G. S. Causon and Mr. A. E. Nicol have been appointed directors. They have been in the company's service for nearly twenty-five years.

MACROME, Ltd., Aldersley, Wolverhampton, states that Mr. William Frost has been appointed representative in South Lancashire in place of Mr. S. Procter, who has left the company's service. Mr. J. Bradley has succeeded Mr. Frost as North Lancashire representative.

Mr. H. T. MEADOWS, M.I.Mar.E., 215, Dashwood House, 69, Old Broad Street, London, E.C.2, has been appointed representative for the United Kingdom and Eire of Guthrie, Murdoch and Co., Ltd., ship repairers, Antwerp. His telephone number is London Wall 5941.

HORSELEY BRIDGE AND THOMAS PIGGOTT, Ltd., Tipton, Staffs, states that, following the merger with Carter-Horseley (Engineers), Ltd., Mr. John Sheffield, chairman, and Mr. Vincent Senior, joint managing director, of the latter company, have joined the board of the parent company, Mr. Sheffield becoming deputy chairman. Mr. J. W. Baillie has resigned from the board of Carter-Horsley (Engineers), Ltd., but continues as managing director of the parent company.

FOUNDRY SERVICES, Ltd., Long Acre, Nechells, Birmingham, 7, announces that Mr. W. D. Cutler is to become its resident representative in Italy. He will work in co-operation with the company's agent, Ditta A. Cesana, Via San Marco, No. 50, Milan. Mr. R. A. Blincoe, 9, Gainsborough Drive, Rochdale, Lancs, is to take over the representation in Lancashire vacated by Mr. Cutler. Foundry Services, Ltd., is forming a manufacturing company in Germany in association with its agents, Firma Hugo Wachenfeld.

## Contracts

DURING March, 1952, the British Electricity Authority placed contracts for equipment for power stations, transforming stations and transmission lines, amounting in the aggregate to £2,070,393. The principal contracts included Littlebrook "C" power station, Dartford, one 60MW turbo-generator set, feed heating and condensing plant (C. A. Parsons and Co., Ltd.); Connah's Quay power station, near Flint, two 30MW turbo-generator sets, feed heating and condensing plants (C. A. Parsons and Co., Ltd.); Doncaster power station, two generator transformers (General Electric Company, Ltd.); Elstree substation, 275kV, 7500MVA switchgear and 132kV, 3500MVA switchgear (A. Reyrolle and Co., Ltd.); and Little Barford-Fulbourne, 132kV double-circuit overhead line (British Insulated Callender's Construction Company, Ltd.).

# British Patent Specifications

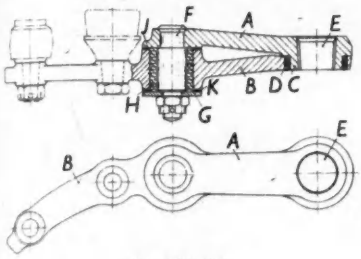
*When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.*

*Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.*

## ROAD TRANSPORT

**669,245.** June 28, 1950.—Steering Linkage of Motor Vehicles, Fiat Societa per Azioni, 300, Corso IV Novembre, Turin, Italy.

The invention relates to a drop arm for the steering linkage of motor vehicles. It consists of two levers pivoted on the same axis and connected together through the interposition of at least one rubber sleeve forming a resilient torque coupling. As the drawing shows, *A* and *B* are two levers mounted about a common pivot, which together constitute the drop arm. The lever *A* is provided at one end with a hub *C* engaging through a rubber sleeve *D* the end of the lever *B*. The tapped hole *E* in the hub engages the spindle rotated by the steer-

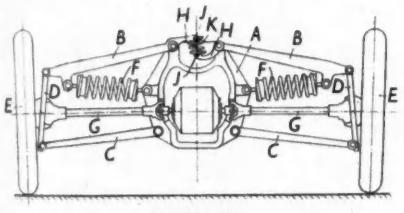



**No. 669,245**

ing box. A nut screwed on the end of the pivot *F* rests on a disc *G* connecting the levers through a rubber sleeve *H* between the pivot, which is fixed to the lever *A*, and the hub of the lever *B*. *J* and *K* are metal discs interposed between the opposite surfaces of levers *A* and *B* and of lever *B* and disc *G*, respectively. The construction affords a resilient torque coupling formed by the rubber member *H*, which prevents transmission to the steering wheel of shocks transmitted by the wheels to the steering linkage.—*April* 2, 1952.

**669,545.** December 31, 1947.—Stabilising Means for Vehicle Spring Suspensions, Jean Albert Gregoire, 92, Avenue Niel, Paris, France.

The invention relates to vehicle suspensions in which the individual wheels are both independently suspended and independently sprung, and further in which the suspensions include arms disposed transversely of the vehicle, such as those of pivoted parallel suspensions. It is intended to provide means to prevent or at least reduce "rolling" when the vehicle is moving in a curved path, especially at speed. In the drawing *A* is the body of the vehicle, to which are pivoted the arms *B* and *C* of the suspension, the outer sides *D* of which




**No. 669,545**

are rigid with the stub axles of wheels *E*. The suspension springs *F* are in tension between the body *A* and arms *B*. The shafts *G* extend between the differential and the wheels, and include Cardan joints. According to the invention, arms *B* extend beyond their point of pivoting on the body to form levers *H* having free ends *J* located one above the other, and between which is a helical spring *K*. This spring constitutes an elastic connection between the arms *B* and, therefore, between the wheels *E*. Modifications in design are also shown in the specification.—*April* 2, 1952.

## TOOLS AND WORKSHOP APPLIANCES

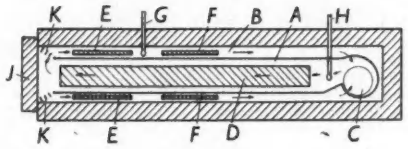
**669,396.** September 30, 1948.—Alloys for Hot Working Tools, Gebr. Böhler and Co., Aktiengesellschaft, 12, Elisabethstrasse, Vienna, I, Austria.

The invention consists of hot working tools made of alloy steel containing 0·10 to 0·70 per cent carbon, 1·00 to 6·00 per cent chromium, and 0·20 to 6·00 per cent niobium, the remainder being iron with the usual impurities. The alloy steel of which the tools are made may further contain additions of 0·2 to 4 per cent tungsten or 0·2 to 6 per cent molybdenum, or 0·1 to 3 per cent vanadium, singly or together, these three constituents being present in an amount preferably not exceeding a total of 10 per cent. An addition of 0·5 to 15 per cent of cobalt may be used further to improve the quality of the alloyed steel. In the case of exceptionally big tools an addition of up to 4 per cent nickel and/or up to 3 per cent manganese and/or up to 2 per cent copper may be advisable. If the operating temperature of the tool should be excessive a content of up to 2 per cent silicon and/or from 0·01 to 3 per cent aluminium has proved advantageous. Dies made of such steels used in extrusion presses are stated to have proved superior to commonly used highly alloyed chromium-tungsten-cobalt steel. These superior qualities, especially the reduced susceptibility to fire checking, are achieved by the patented hot working tools and are due to the combined influence of niobium and chromium and equally molybdenum and tungsten when these two elements are used. Alloys outside the specified range and compositions are not characterised by this reduction of their susceptibility to fire checking. The tools should be oil hardened or air hardened from a temperature of 900 deg. to 1250 deg. Cent. and tempered at temperatures of 300 deg. to 750 deg. Cent.—*April* 2, 1952.

## ELECTRIC FURNACES

**669,351.** April 27, 1949.—Convection Furnaces, Birlec, Ltd., and John Harris, of Birlec Works, Tyburn Road, Erdington, Birmingham, 24.

This invention refers to convection furnaces, in which the work undergoing treatment is heated by the forced circulation of the furnace atmosphere gas. The principal object is to enable the cold or relatively cool work charge, when first inserted into the treatment chamber, to be subjected to an initial superheat without any likelihood of the work or any portion of it being overheated. The furnace shown in the drawing comprises a tubular treatment chamber *A*, which is surrounded by a heating chamber *B*, the atmosphere gas being circulated through the chambers by a fan or blower *C*. A work batch for heat treatment is indicated at *D*. Electric resistors divided into two groups *E* and *F* are provided within the heating chamber. The power input to the resistor groups is so con-



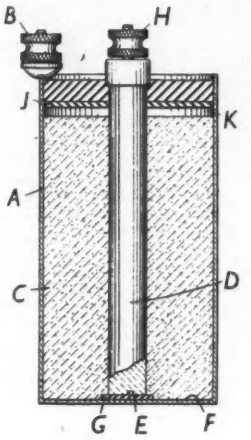

**No. 669,351**

trolled by a main thermocouple *G* between the groups that the same temperature increase is imparted to the circulated atmosphere gas flowing over both groups. The thermocouple is also adapted so to control the power input to the group of resistors *E* that, no matter what is the temperature of the gas before meeting the resistors, the gas always flows from the resistors at a uniform and constant temperature. A second or safety thermocouple *H* is located in the throat or gas discharge outlet from the fan or blower, and is designed to control the power input to the resistors independently of the main thermocouple, to ensure that the temperature of the gas discharged from the fan or blower does not exceed a predetermined maximum. As indicated by the arrows in the drawing, the gas discharged through the throat of the fan or blower flows along the chamber *A* past the work batch *D* towards the furnace door *J*; the reversal in the direction of gas travel to enable the gas to flow through the annular heating chamber is assisted by a system of vanes *K* and whilst passing through the chamber the gas is heated by the groups of resistors *E* and *F* so that it is at a predetermined temperature before returning to the fan or blower. Typical operating temperatures are given in the specification.—*April* 2, 1952.

## ELECTRICAL ENGINEERING

**669,256.** August 15, 1950.—Electric Primary Cell, The Dow Chemical Company, of Midland, County of Midland, State of Michigan, U.S.A.

The invention relates to an improved primary cell utilising metallic magnesium as the anode material. As shown in the drawing, the cell is contained in a case *A* formed of magnesium or magnesium-base alloy. The case also serves as the anode of the cell and may be provided with a terminal *B*. Placed directly in the case is the cathode mixture *C* in direct contact with the inside of the case. A carbon or graphite rod *D* is positioned centrally and tamped around the rod so as to make electrical contact with it. The lower end *E* of the rod is spaced apart from the inside of the bottom *F*. As a safety measure ensuring that the rod does not accidentally touch the bottom an insulating washer *G* is interposed between the lower end of the rod and the bottom, as shown. The top of the electrode may be pro-

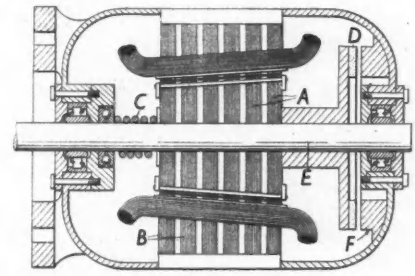



**No. 669,256**

vided with a terminal *H*. An insulating washer of cardboard *J* is placed over the top of the cathode mixture, leaving an air space *K*. The washer is covered with sealing wax. The electrolyte may be any of the alkali metal or alkaline earth metal bromides or ammonium bromide, preferably either magnesium bromide or strontium bromide, dissolved in water in amounts of from about 100 grammes per litre up to saturating amounts. In the specification the composition of the electrolyte is discussed and performance figures given.—*April* 2, 1952.

**669,161.** December 7, 1949.—Electric Motors with Axially Movable Rotors, Gaston Julien van Marck, 351, Paleizenstraat (over de Bruggen), Brussels, II, Belgium.

To obtain a powerful axial force capable of overcoming a considerable reaction, the rotor and stator are disposed as shown. When the motor is stationary, as shown in the drawing, the packets of iron laminations *A* of the rotor are displaced with reference to the corresponding packets of iron laminæ *B* of the stator under the action of a spring *C*. This axial displacement ranges from one to several millimetres. Each packet operates as a small motor, the rotor of which is considerably displaced with respect to the stator. When the windings are energised the rotor is drawn into the magnetic field of the stator and compresses the spring. By this axial displacement the brake shoe




**No. 669,161**

*D* secured on the shaft *E* is disengaged from the fixed brake disc *F*; alternatively this displacement effects the coupling or disengaging of an auxiliary mechanism. Each rotor packet is attracted towards the corresponding stator packets, a slight conicity of approximately 3 deg., that is to say, increases this lateral attraction. The rotor does not tend to pass beyond the optimum position of magnetic attraction and remains perfectly aligned with respect to the stator and is maintained thereby the magnetic field. As a consequence there is an axial displacement without any shock, the magnetic alignment of the rotor and the stator acting as a magnetic damper. This is in contrast to the ordinary conical rotor which hits the abutment violently, as it is not limited in its axial movement by the magnetic field.—*March* 26, 1952.

# Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

**British Institution of Radio Engineers**

*Wed., April 30th.*—N.W. SECTION: College of Technology, Manchester, "V.H.F. Broadcasting: The Case for Amplitude Modulation," J. R. Brinkley, 7.15 p.m.

*Wed., May 7th.*—LONDON SECTION: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, "An Aerial Analogue Computer," W. Saraga, 6.30 p.m.

**Electric Railway Society**

*Thurs., May 1st.*—Fred Tallant Hall, Drummond Stree , London, N.W.1, "The Development of Electric Signalling," P. Gleghorn, 7.15 p.m.

**Illuminating Engineering Society**

*Mon., April 28th.*—LEEDS CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1; Annual General Meeting, 7 p.m.

**Incorporated Plant Engineers**

*To-day, April 25th.*—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Incentives," T. Adams, "Administration," J. Lang, 7.30 p.m.

*Mon., April 28th.*—W. AND E. YORKS BRANCH: The University, Leeds, "How a Technical Knowledge of Timber Can Help a Maintenance Engineer," John Jowett, 7.30 p.m.

**Institute of British Foundrymen**

*Wed., April 30th.*—LONDON BRANCH: Waldorf Hotel, Aldwych, W.C.2, Annual General Meeting, "Surface Finish and Facing Sands," F. Roy Pell, 7 p.m.

**Institute of Economic Engineering**

*Sat., May 3rd.*—Christian Institute, 70, Bothwell Street, Glasgow; Open discussion, 10.30 a.m.

**Institute of Fuel**

*Thurs., May 1st.*—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "The Railways and Coal," R. G. Jarvis, 5.30 p.m.

**Institute of Industrial Supervisors**

*Thurs., May 1st.*—WARRINGTON SECTION: White Hart Hotel, Warrington, "American Foremanship Report," C. R. English, 7 p.m.

**Institute of Refrigeration**

*Tues., April 29th.*—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "Plastics from the Viewpoint of the Refrigeration Industry," V. E. Yarsley, 5.30 p.m.

**Institution of Chemical Engineers**

*To-day, April 25th.*—May Fair Hotel, Berkeley Street, London, W.1, Annual General Meeting, 11 a.m.; Annual Dinner, 7 for 7.30 p.m.

*Sat., May 3rd.*—MIDLANDS BRANCH: The University, Edmund Street, Birmingham, "Stainless Steel in Chemical Plant," A. M. Hucheson, 3 p.m.

**Institution of Civil Engineers**

*Tues., April 29th.*—Great George Street, Westminster, London, S.W.1, "Mechanical Surfacing of Roads," S. M. Lovell, T. U. Wilson and H. E. G. Richards, 5.30 p.m.

*Fri., May 2nd.*—YORKSHIRE ASSOCIATION: Royal Victoria Station Hotel, Sheffield, annual general meeting, "Preparing for and Surfacing of Roads," S. M. Lovell, 7 p.m.

**Institution of Electrical Engineers**

*To-day, April 25th.*—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "The Teaching of Transients and the Use of Operational Methods," opened by D. K. McCleery and H. Tropper, 6 p.m.——N.E. STUDENTS' SECTION: King's College, Newcastle upon Tyne, Annual General Meeting, 6.30 p.m.

*Mon. to Sat., April 28th to May 3rd.*—RADIO SECTION: Savoy Place, London, W.C.2, convention on "The British Contribution to Television."

**Institution of Mechanical Engineers**

*To-day, April 25th.*—Storey's Gate, St. James's Park, London, S.W.1, "Explosions in Enclosed Crankcases of Reciprocating Engines," John Lamb, 5.30 p.m.

*Sat., April 26th.*—YORKSHIRE BRANCH, GRADUATES' SECTION: Technical College, Huddersfield, "Forty-five Years' Experience in Mechanical Handling," J. Ward, 2.30 p.m.

*Wed., April 30th.*—SOUTHERN BRANCH, GRADUATES' SECTION: Royal Aircraft Establishment Technical College, Farnborough, Annual General Meeting, 7 p.m.

*Fri., May 2nd.*—Storey's Gate, St. James's Park, London, S.W.1, "Control and Recovery of Dust and Fume in Industry," R. Ashman; "Filter Efficiency and Standardisation of Test Dust," H. Heywood, 5.30 p.m.

**Institution of Naval Architects**

*Tues., April 29th.*—Polygon Hotel, Southampton, "Rolling of Ships," A. J. Sims, 7.30 p.m.

**Institution of Post Office Electrical Engineers**

*Mon., May 5th.*—Institution of Electrical Engineers, Savoy Place, London, W.C.2, "A General Introduction to Communication Theory," J. E. Flood, L. R. F. Harris and A. D. V. Ridlington, 5 p.m.

**Institution of Structural Engineers**

*Tues., April 29th.*—LANCASHIRE AND CHESHIRE BRANCH: Reynolds Hall, College of Technology, Manchester, "Plasticity and Structural Design," J. A. L. Matheson, 6.30 p.m.——MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, annual general meeting, 6 p.m.

*Wed., April 30th.*—MIDLAND COUNTIES BRANCH, GRADUATES' AND STUDENTS' SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Investigation of the Failure of the Tacoma Narrows Bridge," S. M. Cooper, 7 p.m.

**Junior Institution of Engineers**

*To-day, April 25th.*—39, Victoria Street, London, S.W.1, "Condensed Steam Collection: A New System," A. J. Simpson, 6.30 p.m.

**Leeds Metallurgical Society**

*Thurs., May 1st.*—The University, Leeds, annual general meeting, junior members' papers, 7 p.m.

**Society of Instrument Technology**

*Tues., April 29th.*—Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, London, W.1, "Why the Human Operator?" W. E. Hick, 6.30 p.m.

**Stephenson Locomotive Society**

*Sat., April 26th.*—Special Train Tour of Potteries District; leave Crewe 2.16 p.m.

*Sat., May 3rd.*—Special train tour from Coventry and Nuneaton to Shackerstone, Coalville, Ashby-de-la-Zouch, &c., commencing about 2.25 p.m.

*Sun., May 4th.*—Visit to Swindon Locomotive Works and Running Shed, Western Region, 12.45 p.m.

# British Standards Institution

*All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.*

## METHODS OF MIXING AND VULCANISING RUBBER TEST COMPOUNDS

No. 1674 : 1951. In the course of the revision of the British Standard methods of testing unvulcanised rubber (B.S. 902) and vulcanised rubber (B.S. 903), it became apparent that a new British Standard was required to define precisely the procedures to be adopted for the mixing and vulcanising of all test compounds. The need for this arises where standard vulcanisates have to be prepared for the comparison of physical properties, such as swelling, abrasion resistance and flex cracking. Furthermore, in the evaluation of the vulcanising characteristics of raw rubbers, standard compounds require to be mixed and vulcanised. Different samples of compounding ingredients also may need to be evaluated in a rubber compound. The committee charged with the preparation of this standard was aware of the variety of apparatus in current use in the rubber industry, and the considerable range of mix compositions to which the methods described have to be applied.

This standard therefore lays down the general principles to be followed and the aims to be achieved. Precise details are not given in every case, although recommendations are made, particularly for apparatus. The inclusion of specifications for materials to be used as ingredients in any mixes that may become standardised has not proved to be possible. There is evidence that there are no simple physical tests or chemical analyses which indicate the behaviour of the substances in a rubber mix. The committee therefore express the hope that arrangements will be made in the United Kingdom and Commonwealth, if not internationally, for the more common and important compounding materials, e.g., zinc oxide, sulphur, stearic acid, and two or three accelerators, to be available for standardisation purposes on the lines adopted by the Office of the Rubber Reserve through the National Bureau of Standards in connection with synthetic rubber specifications in the U.S.A.

This standard describes the apparatus and procedure to be adopted in mixing and vulcanising natural rubber compounds, other than those for ebonite and cellular rubber, for subsequent laboratory testing. Price 2s., post free.

## BOLTING FOR THE PETROLEUM INDUSTRY

No. 1750 : 1952. This standard is divided into three parts as follows:—Part 1, alloy steel studbolts, studs, bolts and screws for high-pressure and high-temperature service; Part 2, carbon and alloy steel nuts for high-pressure and high-temperature service; Part 3, carbon steel bolts, stud-bolts, studs and nuts for moderate duty service. The document provides for screw threads in accordance with both B.S. 1580, "Unified Screw Threads," and B.S. 84, "Screw Threads of Whitworth Form," so that the purchaser can select which thread he wishes to use. Part 1 specifies bolting which is equivalent in service to certain grades of bolting in the American Society for Testing Materials Specification A.193, while Part 2 covers nuts which are equivalent in service to certain grades of nuts in A.S.T.M. A.194.

In connection with the interchangeability with the American specifications, it has been considered desirable to have the marking of the British bolting the same as the corresponding American bolting. Each of the three parts contains details of material, heat-treatment, screw threads, dimensions, finish, marking and methods of test. Appendices are included giving details of the grades of steel as well as the design stresses applicable to the materials.

An appendix is also provided giving the information to be supplied by the purchaser. Price 6s. post free.

## RING DOUBLING FRAME BOBBINS

No. 1809 : 1951. The object of this standard is to establish between machine and spindle makers, bobbin makers and users, standard dimensions for ranges of ring doubling frame bobbins. These bobbins may be made from wood, light alloys, plastics, or other suitable materials, and will be interchangeable. Consideration has been given to providing the user with maximum yarn capacity consistent with bobbin strength, and full account has been taken of technical requirements to ensure maximum efficiency in operation.

The range of bobbins dealt with in the specification covers the light, medium, heavy and cabling trades, in lift sizes 6in to 9in inclusive for use in conjunction with ring sizes 1¼in to 5¼in diameter inclusive. Standard spindle dimensions are also given in the specification. Price 4s. post free.

## WELDED STEEL BOILERS FOR HOT WATER CENTRAL HEATING AND HOT WATER SUPPLY

No. 855 : 1952. This standard supersedes B.S. 855 : 1939. It applies primarily to hot water central heating and hot water supply welded steel boilers of over 5 square feet heating surface for operation on systems vented to atmosphere and operating at pressures not exceeding 150ft head (65 lb per square inch), and at temperatures not exceeding 212 deg. Fah., i.e., gravity or accelerated systems. It is divided into two parts.

The first part deals with fuels, rating, heating surface, firegrates, dampers and doors (assembly of boiler), ashpit, boiler openings, inspection and cleaning holes, provision for emptying, marking and materials. The second part describes the method of testing boilers for the determination of the water heating efficiency at rating. Price 6s.

## HOLLOW CLAY BUILDING BLOCKS

No. 1190 : 1951. This standard has been revised to make provision for blocks having a height of 9¼in in order to bond with the deeper type of common brick in use in some parts of the country. The opportunity has been taken to review the requirements generally and to bring them and the test methods up to date. The standard covers blocks for internal walls and partitions and also blocks for structural floors, roofs and similar construction. Dimensions and surface treatment of the various types are given, together with minimum crushing strengths, methods of determining crushing strength and checking for trueness of shape. Price 2s. post free.

# Catalogues

C.A.V., Ltd., Acton, London, W.3.—Catalogue of trolley-bus low-voltage equipment.

SAUNDERS VALVE COMPANY, Ltd., Cwmbran, Newport, Monmouthshire.—Booklet dealing with "Safran" centrifugal pumps.

BIRLEC, Ltd., Tyburn Road, Erdington, Birmingham, 24.—Publications covering all types of Birlec induction heating equipment.

VISCO ENGINEERING COMPANY, Ltd., Stafford Road, Croydon.—Brochure No. 514, describing steel shell water cooling units.

ENGLISH ELECTRIC COMPANY, Ltd., Queens House, Kingsway, London, W.C.2.—Publication dealing with metal-clad switchgear.

PRECISION COMPONENTS (BARNET), Ltd., 13, Byng Road, Barnet, Herts.—Leaflet describing the ten-way double-pole meter switch.

ATLAS DIESEL COMPANY, Ltd., Beresford Avenue, Wembley, Middlesex.—Leaflet E843, describing their range of type "CT" air compressors.

BLAW-KNOX, Ltd., 90–94, Brompton Road, London, S.W.3.—Publication No. BK 143/1, describing the BK–80, 11 cubic yards capacity scraper.

SIMPLEX ELECTRIC COMPANY, Ltd., Broadwell, Oldbury, Birmingham.—"Lundberg Accessories," specification folder (Serial No. LA 1908).

B. AND A. ENGINEERING COMPANY, Ltd., 50, Pall Mall, London, S.W.1.—Leaflet describing a special device developed to prevent grabs from twisting.

FOSTER INSTRUMENT COMPANY, Ltd., Letchworth, Herts.—Catalogue No. 103, giving details of instruments for temperature measurement and control.

HUGH SMITH AND CO. (POSSIL), Ltd., Possil Engine Works, Glasgow.—Booklet illustrating machine tools for shipbuilding, locomotive building and boiler works.

CHASESIDE ENGINEERING COMPANY. Ltd., Station Works, Hertford, Hertfordshire.—Leaflet entitled "Take the Backache out of Building with the Chaseside."

DAVIDSON AND CO., Ltd., Sirocco Engineering Works, Belfast, Northern Ireland.—Publication Ref. SF400, illustrating and describing pneumatic conveying installations.